

1. JP,2754744,B

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CLAIMS

(57) [Claim(s)]

[Claim 1] The fuel-oil-consumption control unit of the internal combustion engine which controls the fuel oil consumption from a fuel injection valve in conformity with the fuel behavior model which is characterized by providing the following, and which described the fuel behavior in an internal combustion engine by making adhesion fuel quantity to an inlet-pipe wall surface into a state variable. A model parameter estimation means to presume the model parameter of the above-mentioned fuel behavior model based on the operational status of an internal combustion engine, and to update this fuel behavior model. An adhesion fuel quantity presumption means to presume the adhesion fuel quantity to an inlet-pipe wall surface according to the fuel behavior model by which updating was carried out [above-mentioned] based on the fuel oil consumption from the above-mentioned fuel injection valve. A fuel quantity calculation means in a target cylinder to compute the fuel quantity in a target cylinder which should be supplied in the cylinder of an internal combustion engine according to the operational status of an internal combustion engine. The presumed result of the above-mentioned model parameter estimation means or the above-mentioned adhesion fuel quantity presumption means, A control error estimation means to presume the control error of the fuel quantity in a cylinder based on the transient operational status of an internal combustion engine, It is based on the presumed this control error. the above-mentioned fuel quantity in a target cylinder The fuel quantity amendment means in an amendment target cylinder, A fuel-oil-consumption calculation means to compute the fuel oil consumption from the above-mentioned fuel injection valve according to the fuel behavior model by which updating was carried out [above-mentioned] based on the amendment result of this fuel quantity amendment means in a target cylinder, and the presumed result of the above-mentioned adhesion fuel presumption means.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[Industrial Application]

this invention relates to the fuel-oil-consumption control unit of the internal combustion engine which controls fuel oil consumption in conformity with the fuel behavior model which described the fuel behavior in an internal combustion engine.

[Description of the Prior Art]

the fuel conventionally supplied to an internal combustion engine -- as one of the fuel-oil-consumption control units which control the fuel oil consumption from a fuel injection valve so that the air-fuel ratio of a gaseous mixture turns into a target air-fuel ratio Amendment correction value for the basic fuel oil consumption calculated to JP,59-196930,A from the rotational speed and the inhalation air content of an internal combustion engine like a publication For example, a control input, Make into a control output the actual measurement of the air-fuel ratio detected using an air-fuel ratio sensor, and it identifies as that of which alignment approximation consists between this control input and a control output. It asks for the mathematical model which describes dynamic behavior of an internal combustion engine, and the control unit based on the so-called linear control theory which controls fuel oil consumption by the control law designed based on this is known.

However, the mathematical model had to be set up for two or more operating range of every which can be regarded as linear approximation being realized like a publication in JP,59-7751,A in order to control good by the ability describing behavior dynamic [of an internal combustion engine] in the relation between the above-mentioned control input and a control output being nonlinear originally, and having only asked for the mathematical model by linear approximation as mentioned above only under a very narrow service condition, and the control law had to be determined for every operating range based on this. For this reason, in the former, the control law had to be changed for every operating range of an internal combustion engine, and there was a problem that control became complicated. Moreover, in the boundary point of each operating range, there is also a problem that control benefits the change of a control law unstable.

Then, the applicant for this patent was determining the control law by which nonlinear compensation was carried out based on the fuel behavior model which described the fuel behavior in an internal combustion engine by making adhesion fuel quantity to an inlet-pipe wall surface, and evaporation fuel quantity within an inlet pipe into a state variable by Japanese Patent Application No. No. 189889 [62 to], Japanese Patent Application No. No. 189891 [62 to], etc., and he proposed the fuel-oil-consumption control unit which can perform fuel-oil-consumption control (by namely, one control law), without changing a control law as mentioned above.

[Problem(s) to be Solved by the Invention]

However, it may be difficult to describe the fuel behavior of an internal combustion engine completely also with the above-mentioned fuel behavior model, and an error may produce it to a model in fact by transient operation of an internal combustion engine, with-time change of a fuel-injection system, etc. And if such a model error arises, the control law based on this will stop corresponding with an internal combustion engine, and the problem that the control precision of an air-fuel ratio falls will occur.

then, the control error accompanying the model error of a fuel behavior model in this invention -- precision -- good -- an amendment -- it was made for the purpose of offering the fuel-oil-consumption control unit of the internal combustion engine which can do things

[Means for Solving the Problem]

Namely, the composition of this invention made since the above-mentioned purpose was attained It illustrates to a view 1 and needs. It is the fuel-oil-consumption control unit of the internal combustion engine which controls the fuel oil consumption from a fuel injection valve M3 in conformity with the fuel behavior model which described the fuel

behavior in an internal combustion engine M2 by making adhesion fuel quantity to inlet-pipe M1 wall surface into a state variable. A model parameter estimation means M4 to presume the model parameter of the above-mentioned fuel behavior model based on the operational status of the internal combustion engine M2, and to update this fuel behavior model. An adhesion fuel quantity presumption means M5 to presume the adhesion fuel quantity to inlet-pipe M1 wall surface according to the fuel behavior model by which updating was carried out [above-mentioned] based on the fuel oil consumption from the above-mentioned fuel injection valve M3. A fuel quantity calculation means M6 in a target cylinder to compute the fuel quantity in a target cylinder which should be supplied in the cylinder of an internal combustion engine M2 according to the operational status of the internal combustion engine M2. The presumed result of the above-mentioned model parameter estimation means M4 or the above-mentioned adhesion fuel quantity presumption means M5. A control error estimation means M7 to presume the control error of the fuel quantity in a cylinder based on the transient operational status of an internal combustion engine M2. It is based on the presumed this control error. the above-mentioned fuel quantity in a target cylinder The fuel quantity amendment means M8 in an amendment target cylinder. A fuel-oil-consumption calculation means M9 to compute the fuel oil consumption from the above-mentioned fuel injection valve M3 according to the fuel behavior model by which updating was carried out [above-mentioned] based on the amendment result of the this fuel quantity amendment means M8 in a target cylinder, and the presumed result of the above-mentioned adhesion fuel presumption means M5. The fuel-oil-consumption control unit of the internal combustion engine characterized by ***** is made into the summary.

[Function]

In the fuel-oil-consumption control unit of this invention constituted as mentioned above, the model parameter estimation means M4 updates the fuel behavior model which presumes the model parameter of a fuel behavior model based on the operational status of an internal combustion engine M2, and is used for control, and the adhesion fuel quantity presumption means M5 presumes the adhesion fuel quantity to inlet-pipe M1 wall surface according to the updated fuel behavior model. Moreover, the fuel quantity in a target cylinder from which the fuel quantity calculation means M6 in a target cylinder serves as control objectives according to the operational status of an internal combustion engine M2 is computed, and the control error estimation means M7 presumes the control error of the fuel quantity in a cylinder based on the presumed result of the model parameter estimation means M4 or the above-mentioned adhesion fuel quantity presumption means M5, and the transient operational status of an internal combustion engine M2. Then, the fuel quantity amendment means M8 in a target cylinder amends the fuel quantity in a target cylinder based on this presumed control error, and the fuel-oil-consumption calculation means M9 computes the fuel oil consumption from a fuel injection valve M3 based on the wall surface adhesion fuel quantity presumed with the fuel quantity in this amended target cylinder, and the adhesion fuel quantity presumption means M5.

Namely, it computes fuel oil consumption by this invention presuming the control error resulting from the model error produced at the time of transient operation of an internal combustion engine M2 based on the adhesion fuel quantity and the transient operational status of an internal combustion engine M2 which were presumed with the model parameter or the adhesion fuel quantity presumption means M5 presumed with the model parameter estimation means M4, and amending the fuel quantity in a target cylinder which serves as control objectives by the presumed result. Consequently, fuel oil consumption will be set up as a value which considered the control error beforehand, and it becomes possible [performing fuel-oil-consumption control], without producing a control error, even if transient operation of the internal combustion engine M2 is carried out.

Moreover, it is canceled by updating the fuel behavior model which presumes a model parameter and determines a control law, and the model parameter estimation means M4 of the control error resulting from the model error produced by aging of an internal combustion engine M2 can improve control precision also by this.

[Example]

The example of this invention is explained with a drawing below.

A view 2 is an outline block diagram showing the composition of the internal combustion engine 2 with which this invention was applied, and its peripheral device first.

As shown in drawing, to the inlet pipe 4 of an internal combustion engine 2 It has the intake-pressure sensor 12 which detects the pressure P_m in the air cleaner 6 which purifies inhalation air, the throttle valve 8 which controls an inhalation air content, the surge tank 10 which suppresses throb of inhalation of air, and a surge tank 10 (pressure-of-induction-pipe force), and the intake temperature sensor 14 which detects an intake-air temperature T_a . the fuel which flowed in cylinder 2a of an internal combustion engine 2 from the oxygen component under exhaust air upstream from the three way component catalyst 18 which purifies exhaust air in an exhaust pipe 16, and the three way component catalyst 18 -- it has the fuel-air-ratio sensor 19 which detects the fuel-air ratio λ of a gaseous mixture (inverse number of air-fuel ratio A/F)

Moreover, the internal combustion engine 2 concerned is equipped with the coolant temperature sensor 26 grade which

detects the rotational-speed sensor 22 for detecting the rotational speed N_e of an internal combustion engine 2 from rotation of the distributor 20 besides the above-mentioned intake-pressure sensor 12, an intake temperature sensor 14, and the fuel-air-ratio sensor 19, the crank angle sensor 24 for similarly detecting the fuel-injection timing from rotation of a distributor 20 to an internal combustion engine 2, and the cooling water temperature T_w of an internal combustion engine 2 as a sensor for detecting the operational status. In addition, a distributor 20 is for impressing the high voltage from an ignitor 28 to an ignition plug 29 by predetermined ignition timing.

And the detecting signal from each above-mentioned sensor is used for it being inputted into the electronic control circuit 30 constituted as a logic operation circuit centering on a microcomputer, driving a fuel injection valve 32, and controlling the fuel oil consumption from a fuel injection valve 32.

Namely, the electronic control circuit 30 Although data processing is performed by CPU40 and CPU40 which perform data processing for fuel-oil-consumption control according to the control program set up beforehand ROM42 on which required control BUROGURAMU and a required initial data were recorded beforehand, and although data processing is similarly performed by CPU40 It consists of output ports 48 for outputting a driving signal to a fuel injection valve 32 according to the input port 46 for the data used inputting RAM44 and the detecting signal from each above-mentioned sensor which are written temporarily, and the result of an operation in CPU40 etc. the fuel which flows in cylinder 2a of an internal combustion engine 2 -- the fuel oil consumption from a fuel injection valve 32 is controlled so that the fuel-air ratio λ of a gaseous mixture is set to predetermined target fuel-air-ratio λ_{bda} Next, it explains based on the block diagram showing the control law of the fuel-oil-consumption control performed by this electronic control circuit 30 in a view 3.

A **** 3 view is drawing showing the control law of the example concerned, hard composition is not shown and actual fuel-oil-consumption control is realized by execution of a series of control programs shown in the below-mentioned flow chart of a view 4.

Moreover, this control law is based on the fuel behavior model shown in the following formula (1) which described the behavior of the fuel which flows in cylinder 2a of an internal combustion engine 2 by making adhesion fuel quantity f_w to inlet-pipe 4 wall surface into a state variable, and (2) so that it may mention later. A suffix (k) shall be given to a value at present, a suffix (k-1) shall be given to the value in front of 1 cycle, and it shall express [in / the following explanation / are designed so that fuel oil consumption may be computed for every cycle of an internal combustion engine 2, and].

$$f_w(k+1) = P \cdot f_w(k) + R \cdot f_i(k)$$

-- (1)

$$f_c(k) = (1-P) f_w(k) + (1-R) f_i(k) \text{ -- (2)}$$

(However, f_i :fuel oil consumption, the fuel quantity in f_c :cylinder, P, R:constant)

As shown in a view 3, in this example, the pressure-of-induction-pipe force P_m first acquired by the detecting signal from the intake-pressure sensor 12, an intake temperature sensor 14, and the rotational-speed sensor 22, an intake-air temperature T_a , and rotational speed N_e are inputted into the inflow air-content presumption machine A1 in a cylinder. The inflow air-content presumption machine A1 in a cylinder is based on the pressure-of-induction-pipe force P_m in which above-mentioned are for presuming the air content (inhalation air content in a cylinder) m_c which flows into cylinder 2a of an internal combustion engine 2, and it was each inputted at the time of an intake stroke, an intake-air temperature T_a , and rotational speed N_e , and is the following formula (3).

$$m_c = \{ \text{betax}(N_e) \text{ and } P_m - \text{beta } y \} (N_e) / T_a \text{ -- (3)}$$

The inhalation air content m_c in a cylinder is presumed using (however, the function of the $\text{betax}(N_e)$ $\text{betay}(N_e)$:rotational speed N_e).

Moreover, next, each data of the above-mentioned pressure-of-induction-pipe force P_m and rotational speed N_e is inputted also into the target fuel-air-ratio setter A2 with the cooling water temperature T_w obtained by the detecting signal from a coolant temperature sensor 26. It is for setting up fuel-air-ratio (target fuel-air ratio) λ_{bda} of a gaseous mixture. the fuel which should supply the target fuel-air-ratio setter A2 to an internal combustion engine 2 -- Based on each above-mentioned input data, the load operational status of an internal combustion engine 2, warming-up operational status, etc. are searched for. When there is the need that the time of an internal combustion engine 2 being in the heavy load operational status at the time of acceleration etc. and the cooling water temperature T_w warm up an internal combustion engine 2 low, target fuel-air-ratio λ_{bda} is set as the value by the side of [than the theoretical air fuel ratio from which an excess air factor is set to 1 / more / the amount of fuel] rich. When an internal combustion engine 2 is in the light load operational status at the time of a slowdown etc., target fuel-air-ratio λ_{bda} is set as the value by the side of RIN fewer than theoretical air fuel ratio for fuel, and at the time of the other usual operation, target fuel-air-ratio λ_{bda} is set as the value corresponding to theoretical air fuel ratio.

And target fuel-air-ratio λ_{bda} set up by the inflow air content m_c in a cylinder and the target fuel-air-ratio setter A2

which were presumed with the inflow air-content presumption vessel A1 in a cylinder in this way is inputted into the fuel quantity computing element A3 in a target cylinder, and is changed into the fuel quantity fcr in a target cylinder used as control objectives. That is, this fuel quantity computing element A3 in a target cylinder is equivalent to the above-mentioned fuel quantity calculation means M6 in a target cylinder, and computes the fuel quantity fcr (=mc-lambda_{dar}) in a target cylinder by multiplying by the inflow air content mc in a cylinder, and target fuel-air-ratio lambda_{dar}.

Moreover, next, the pressure-of-induction-pipe force P_m is inputted also into the amount computing element A4 of target fuel amendments. The amount computing element A4 of target fuel amendments the control error of the fuel quantity in a cylinder resulting from the model error of the fuel behavior model produced at the time of transient operation of an internal combustion engine 2. It is for computing as an amount of amendments to the fuel quantity fcr in a target cylinder computed by the fuel quantity computing element A3 in a target cylinder. It is based on a constant alpha and is [the model parameters (namely, constant in the above (1) and (2) formulas) P and R of the fuel behavior model called for with the below-mentioned identification vessel A7, the variation of the pressure-of-induction-pipe force P_m detected by the intake-pressure sensor 12, and] the following formula (4).

$$\delta fcr(k) = \alpha \cdot \frac{P_m(k) - P_m(k-1)}{1 - R} \quad \dots (4)$$

Amount of ***** fuel amendments deltafcr is computed. In addition, this amount computing element A4 of target fuel amendments is equivalent to the above-mentioned control error estimation means M7.

And this computed amount of fuel amendments deltafcr is inputted into subtractor A5 as a fuel quantity amendment means M8 in a target cylinder with the fuel quantity fcr in a target cylinder computed by the fuel quantity computing element A3 in a target cylinder, is subtractor A5, subtracts amount of fuel amendments deltafcr from the fuel quantity fcr in a target cylinder, and the fuel quantity fc in a target cylinder is used for an amendment's.

Next, it is inputted into the 1st fuel-oil-consumption computing element A6 with the model parameters P and R of the fuel behavior model called for with the below-mentioned identification vessel A7 as a result of [of subtractor A5 / fcrh] subtraction (i.e., the fuel quantity in an amendment target cylinder) (= fcr-delta fcr).

The 1st fuel-oil-consumption computing element A6 is equivalent to the above-mentioned adhesion fuel quantity presumption means M5 and the above-mentioned fuel-oil-consumption calculation means M9, and presumes the adhesion fuel quantity fw to the inlet-pipe wall surface 4 using the following formula (5) for every fuel injection from a fuel injection valve 32 first. fw(k+1)=P-fw(k)+R-fi (k)

-- (5)

(However, the fuel oil consumption from the fi(k):fuel injection valve 32, the estimate of fw(k):last time, P, the model parameter for which it asked with R:identification vessel A7)

It is based on the fuel quantity fcrh in an amendment target cylinder by which the input was carried out [above-mentioned] with the presumed result fw, and is the following formula (6).

$$fi = \frac{fcrh - (1 - P) fw}{1 - R} \quad \dots (6)$$

The fuel oil consumption fi for performing fuel fuel injection to a degree from a fuel injection valve 32 is computed using (the model parameter for which it asked with P and R:identification vessel A7).

In addition, in this 1st fuel-oil-consumption computing element A6, the initial value (this example 0) set up beforehand is used for the adhesion fuel quantity estimate of the last time at the time of presuming the adhesion fuel quantity fw at the time of a control start.

Next, it is for presuming the model parameters P and R of the fuel behavior model which the identification machine A7 was equivalent to the above-mentioned model parameter estimation means M4, and was described by the above (1) and (2) formulas. It is based on the fuel quantity (inflow fuel quantity in a real cylinder) fc which actually flowed in cylinder 2a presumed with the inflow fuel quantity presumption vessel A8 in a cylinder, the false adhesion fuel quantity fwg computed by 2nd fuel-oil-consumption computing-element A9, and the false fuel oil consumption fig. As shown in the following formula (7) and (8), the model parameters P and R are presumed.

$$P(k) = P(k-1) - k1(k) - E(k)$$

-- (7)

$$R(k) = R(k-1) - k2(k) - E(k)$$

-- (8)

however, the above (7) and (8) formulas -- setting -- $E(k) = f_c(k) - \{1 - P(k-1)\} \text{fwg}(k)$

+ $\{1 - R(k-1)\} \text{fig}(k)$ -- (9)

$k1(k) = \{h11(k-1)\text{fwg}(k) + h12(k-1)\text{fig}(k)\}$

$/[\rho + h11(k-1)\text{fwg2}(k) + \{h21(k-1) + h12(k-1)\} \text{fwg}(k) \text{fig}(k) + h22(k-1) \text{fig2}(k)]$ -- (10)

$k2(k) = \{h21(k-1)\text{fwg}(k) + h22(k-1)\text{fig}(k)\}$

$/[\rho + h11(k-1)\text{fwg2}(k) + \{h21(k-1) + h12(k-1)\} \text{fwg}(k) \text{fig}(k) + h22(k-1) \text{fig2}(k)]$ -- (11)

It comes out. Moreover, in these (10) and (11) formulas, ρ is the constant ($0 < \rho \leq 1$) set up beforehand, as mentioned later, and $h11(k-1)$ - $h22(k-1)$ are the values computed last time (namely, 1 cycle before) using following formula (12) - (15).

$h11(k) = [h11(k-1) - k1(k) \{h11(k-1)\text{fwg}(k) + h21(k-1) \text{fig}(k)\}] / \rho$ -- (12)

$h12(k) = [h12(k-1) - k1(k) \{h12(k-1)\text{fwg}(k) + h22(k-1) \text{fig}(k)\}] / \rho$ -- (13)

$h21(k) = [h21(k-1) - k2(k) \{h11(k-1)\text{fwg}(k) + h21(k-1) \text{fig}(k)\}] / \rho$ -- (14)

$h22(k) = [h22(k-1) - k1(k) \{h12(k-1)\text{fwg}(k) + h22(k-1) \text{fig}(k)\}] / \rho$ -- (15)

Next, the inflow fuel quantity presumption machine A8 in a cylinder is for presuming the fuel quantity (inflow fuel quantity in a real cylinder) f_c which actually flowed in cylinder 2a as mentioned above, is multiplying by the real fuel-air ratio λ obtained by the detecting signal from the fuel-air-ratio sensor 19, and the inflow air content m_c in a cylinder calculated with the inflow air-content presumption vessel A1 in a cylinder, and presumes the inflow fuel quantity $f_c (= \lambda m_c)$ in a real cylinder.

The 2nd fuel-oil-consumption computing element A9 again as the fuel oil consumption used in case the model parameters P and R are presumed, and adhesion fuel quantity I is for setting up the false fuel oil consumption fig and the adhesion fuel quantity fwg which were computed as a thing without a model error. The false adhesion fuel quantity fwg to the inlet-pipe wall surface 4 is presumed like the 1st fuel-oil-consumption computing element A6 using the following formula (16) for every fuel injection from a fuel injection valve 32. $\text{fwg}(k+1) = P \cdot \text{fwg}(k) + R \cdot \text{fig}(k)$

-- (16)

It is based on the presumed result fwg and the fuel quantity f_{cr} in a target cylinder computed by the fuel quantity computing element A3 in a target cylinder, and is the following formula (17).

$$\text{fig} = \frac{f_{cr} - (1 - P) \text{fwg}}{1 - R} \quad \dots (17)$$

The false fuel oil consumption fig is computed using (the model parameter for which it asked with P and R :identification vessel A7).

In addition, in this 1st fuel-oil-consumption computing element A9, the initial value (this example 0) set up beforehand is used for the adhesion fuel quantity estimate of the last time at the time of presuming the adhesion fuel quantity fwg at the time of a control start.

Next, the design method of the above-mentioned control law based on the fuel behavior model described by the above (1) and (2) formulas and this fuel behavior model is explained.

The fuel quantity f_c which flows in cylinder 2a of an internal combustion engine 2 first, i.e., the fuel quantity in a cylinder, can be described like the following formula (18) using the fuel oil consumption f_i from a fuel injection valve 32, the adhesion fuel quantity f_w to inlet-pipe 4 wall surface, and the evaporation fuel quantity f_v in the inlet-pipe 4 interior.

$f_c = \alpha_1 f_i + \alpha_2 f_w + \alpha_3 f_v$ -- (18)

That is, since it is thought that the above-mentioned fuel quantity f_c is total with the direct inflow α_1 of the injection fuel from a fuel injection valve 32, f_i , the indirect inflow α_2 from the inlet pipe 4 to which the injection fuel adhered and f_w , and the inflow α_3 of the evaporation fuel which exists in the inlet-pipe 4 interior by evaporation of injection fuel or wall surface adhesion fuel and f_v , the fuel quantity f_c which flows in cylinder 2a like an upper formula (18) can be described.

In an upper formula (18), since fuel oil consumption f_i becomes settled by the valve-opening time of a fuel injection valve 32, if the adhesion fuel quantity f_w to inhalation-of-air cylinder 4 wall surface and the evaporation fuel quantity f_v within an inlet pipe 4 can be known, fuel quantity f_c can be predicted.

Then, the above-mentioned adhesion fuel quantity f_w and the evaporation fuel quantity f_v are considered below. First, according to an inflow into cylinder 2a at the time of an intake stroke, at the time of an intake stroke, the adhesion fuel quantity f_w to inlet-pipe 4 wall surface increases, when a part of the fuel oil consumption f_i α_4 which α_2 decreases in part, and also decreases by evaporation to the inlet-pipe 4 interior, and is injected from a fuel injection valve 32 synchronizing with rotation of an internal combustion engine 2 adheres. Moreover, the fuel evaporation per 1 cycle of an internal combustion engine 2 can be expressed as α_5 and V_f/N_e ($=\alpha_5$, V_{fw} , α_5 :proportionality constant) from the fuel evaporation V_f per unit time (namely, fuel vapor rate), and the rotational speed N_e of an internal combustion engine 2. For this reason, the adhesion fuel quantity f_w to inlet-pipe 4 wall surface can be described as shown in the following formula (19).

$$f_w(k+1) = (1-\alpha_2) f_w(k) + \alpha_4 f_i(k) - \alpha_5 V_{fw}(k) \quad \dots (19)$$

On the other hand, according to an inflow into cylinder 2a at the time of an intake stroke, for every cycle of an internal combustion engine 2, the evaporation fuel quantity f_v in the inlet-pipe 4 interior increases, when [the] α_3 decreases in part and also a part of fuel oil consumption f_i α_6 evaporates, and it increases by fuel evaporation of the above-mentioned adhesion fuel further.

For this reason, the evaporation fuel quantity f_v in an inlet pipe 4 can be described as shown in the following formula (20).

$$f_v(k+1) = (1-\alpha_3) f_v(k) + \alpha_6 f_i(k) + \alpha_5 V_{fw}(k) \quad \dots (20)$$

In the above-mentioned (18) - (20) formula, $(1-\alpha_2)$ therefore, by arranging Q and α_4 for P and $(1-\alpha_3)$, and arranging S and α_5 for R and α_6 as D The following formula (21) and the fuel behavior model like (22) which made the state variable the adhesion fuel quantity and evaporation fuel quantity to an inhalation-of-air barrel wall side, and were expressed by the discrete time system by making 1 cycle of an internal combustion engine 2 into a sampling period become settled.

$$\begin{bmatrix} f_w(k+1) \\ f_v(k+1) \end{bmatrix} = \begin{bmatrix} P & 0 \\ 0 & Q \end{bmatrix} \cdot \begin{bmatrix} f_w(k) \\ f_v(k) \end{bmatrix} + \begin{bmatrix} R \\ S \end{bmatrix} \cdot f_i(k) + \begin{bmatrix} -D \\ +D \end{bmatrix} \cdot V_{fw}(k) \quad \dots (21)$$

$$f_c(k) = \begin{bmatrix} 1-P & 1-Q \end{bmatrix} \begin{bmatrix} f_w(k) \\ f_v(k) \end{bmatrix} + (1-R-S) f_i(k) \quad \dots (22)$$

In such a fuel behavior model, if it sets by the method of identifying common knowledge of each model parameters P , Q , R , S , and D , all operating range can describe mostly the fuel behavior at the time of steady operation of an internal combustion engine to accuracy. however, in the above-mentioned fuel behavior model, as the term of the conventional technology also described, even if it may be able to stop being able to describe correctly the fuel behavior which is practice by transient operation of an internal combustion engine 2 or with-time change of an internal combustion engine 2 and designs a control law, using this fuel behavior model as it is, good control precision may not be obtained. Then, in this example, it sets to the fuel behavior model described by the above (21) and (22) formulas. The evaporation fuel quantity f_v and the fuel evaporation V_{fw} which are remarkably small compared with the adhesion fuel quantity f_w and fuel oil consumption f_i , and do not have big influence on fuel behavior are disregarded. Like the above (1) and (2) formulas, the simplified fuel behavior model is created, and the control law is designed so that the control error produced by simplification of a model, transient operation of an internal combustion engine 2, with-time change

of an internal combustion engine 2, etc. can be compensated based on this fuel behavior model.

That is, if there is no error in the fuel behavior model first described by the above (1) and (2) formulas, the fuel oil consumption f_i for controlling the fuel quantity f_c in a cylinder to the fuel quantity f_{cr} in a target cylinder can be calculated like the following formula (23) by transforming the output equation {(2) formulas} of the above-mentioned fuel behavior model.

$$f_i = \frac{f_{cr} - (1 - P) f_w}{1 - R} \quad \dots (23)$$

However, in the above-mentioned fuel behavior model, since an error arises by simplification of a model, transient operation of an internal combustion engine 2, with-time change of an internal combustion engine 2, etc., if it controls using this (23) formula as it is, a control error will occur.

Then, the identification machine A7 for presuming that the model parameters P and R mentioned above is formed, the model parameters P and R are serially presumed with this identification vessel A7, and it is made to compute fuel oil consumption f_i in this example using these model parameters P and R of the presumed newest.

Moreover, although good fuel-injection control can be performed at the time of steady operation of an internal combustion engine 2 when computing fuel oil consumption f_i by presuming the model parameters P and R with the identification vessel A7 in this way, at the time of transient operation to which the operational status of an internal combustion engine 2 changes suddenly, an error arises in the estimate P and R of a model parameter according to the detection delay of the operational status of an internal combustion engine 2 etc., and a control error occurs by this. For this reason, the amount computing element A4 of target fuel amendments and subtractor A5 are prepared for the control error accompanying the model error further produced at the time of such transient operation in an amendment sake, and the fuel quantity f_{cr} in a target cylinder computed by the fuel quantity computing element A3 in a target cylinder is amended, and it is made to compute fuel oil consumption f_i with the fuel quantity f_{crh} in this amended amendment target cylinder in this example.

Hereafter, the design procedure of the amount computing element A4 of target fuel amendments for such a model error compensation and the identification machine A7 is explained.

First, in the above (1) and (2) formulas, Z transform is performed and the transfer function of a system is searched for.

When the Z transform of the above (1) and (2) is carried out, it is $Zf_w(Z) = Pf_w(Z) + Rf_i(Z)$. -- (24)

$f_c(Z) = (1-P) f_w(Z) + (1-R) f_i(Z)$ -- (25)

It becomes. Moreover, an upper formula (24) to $f_w(Z)$ is the following formula (26).

$$f_w(Z) = \frac{R \cdot f_i(Z)}{Z - P} \quad \dots (26)$$

** -- it can describe like Then, when an upper formula (26) is substituted for (25) formulas, it is.

$$f_c(Z) = \frac{(1-R)Z + (R-P)}{Z - P} f_i(Z) \quad \dots (27)$$

The transfer function of a next door and a system is acquired.

On the other hand, if the error of the model parameter estimation values P and R produced at the time of transient operation is set to delta in the above (1) and (2) formulas, the following formula (28) and the fuel behavior model like (29) will be obtained.

$f_w(k+1) = P \cdot f_w(k) + R \cdot f_i(k) - \delta(k)$ -- (28)

$f_c(k) = (1-P) f_w(k) + (1-R) f_i(k) + \delta(k)$ -- (29)

If Z transform is performed in these (28) and (29) formulas and the transfer function of a system is searched for like the above, it will become like the following formula (30).

$$f_c(Z) = \frac{(1-R)Z + (R-P)}{Z-P} f_i(Z) + \frac{Z-1}{Z-P} \delta(Z) \quad \dots (30)$$

Next, in the system described by the above-mentioned (27) formula, the fuel oil consumption f_i for controlling the fuel quantity f_c in a cylinder to the fuel quantity f_{cr} in a target cylinder will become like the following formula (31), if an inverse transfer function is used.

$$f_i(Z) = \frac{Z-P}{(1-R)Z + (R-P)} f_{cr}(Z) \quad \dots (31)$$

And if this (31) formula is substituted for the above-mentioned (30) formula, the transfer function over the desired value at the time of controlling fuel oil consumption regardless of the model error δ will be acquired like the following formula (32).

$$f_c(Z) = f_{cr}(Z) + \frac{Z-1}{Z-P} \delta(Z) \quad \dots (32)$$

Therefore, control error δf_{cr} of the fuel quantity f_c in a cylinder by the model error δ can be found like the following formula (33) from this (32) formula.

$$\delta f_{cr}(Z) = \frac{Z-1}{Z-P} \delta(Z) \quad \dots (33)$$

Such control error δf_{cr} is cancelable by changing the fuel quantity in a cylinder used as control objectives into the value (namely, fuel quantity in an amendment target cylinder computed in above-mentioned subtractor A5) f_{crh} which subtracted the fuel quantity for control error δf_{cr} from the fuel quantity f_{cr} in a target cylinder. For this reason, in this example, the above-mentioned (6) formulas used in order to compute the fuel oil consumption f_i from a fuel injection valve 32 in the 1st fuel-oil-consumption computing element A6 by changing the fuel quantity f_{cr} in a target cylinder in the above-mentioned (23) formula into the fuel quantity f_{crh} in an amendment target cylinder are set up. Although it is difficult to, determine this control error δf_{cr} on the other hand, in actual control, control error δf_{cr} can be experimentally patternized as a function of the parameter showing the transient operational status of an internal combustion engine 2. Moreover, the model parameters P and R change and this control error δf_{cr} becomes so large that the adhesion fuel to inlet-pipe 4 wall surface increases. Then, the above-mentioned operation expression for control error calculation (4) is set up so that it may compute as a function of the variation of the pressure-of-induction-pipe force P_m which control error δf_{cr} is proportioned in $P/(1-R)$, and expresses the transient of an internal combustion engine 2 from the index and bird clapper to which $P/(1-R)$ expresses with this example the grade in which fuel oil consumption f_i adheres to an inlet-pipe wall surface.

Next, it is made for the identification machine A7 which presumes the model parameters P and R to have the model parameter presumed in conformity with an algorithm index load type the second [a minimum of] power. In addition, about the technique of such a parameter identification, since it is explained in full detail in 489, inside ***** "identification technique -1 of linear-discrete time system" system, control, Vol.25, No.8, P476 - P1981, etc., detailed explanation is omitted.

With namely, the parameter estimation problem by the least square method It is asking for the model parameter which makes the minimum the performance index J like the following formula (35) when describing. $e(k) = f_c(k) - (1-P) f_w(k) - (1-R) f_i(k)$ model error [of a fuel behavior model] $e(k)$ -- an output equation {(2) formulas} -- deforming -- the following formula (34) -- it needs -- (34)

$$J = \sum_{i=0}^k \rho^{k-i} \cdot \{e(k)\}^2 \quad \dots (35)$$

They are the value ($1 < \rho \leq 0$) set up between 0 and 1, and ρ , however, are Forgetting Factor for making weight small and decreasing the contribution to estimate, so that they become a past value. }
 A serial calculation type algorithm for this, $\Theta(k) = [P(k) \quad R(k)]^T \dots (36)$

$$Z(k) = [f_w(k) \quad f_i(k)]^T \dots (37)$$

$$y(k) = f_c(k) \dots (38)$$

$$\Theta(k) = \Theta(k-1) + K(k) [y(k) - Z^T(k) \cdot \Theta(k-1)] \dots (39)$$

When it carries out,

$$K(k) = H(k-1) \cdot Z(k) [\rho + Z^T(k) \cdot H(k-1) \cdot Z(k)]^{-1} \dots (40)$$

$$H(k) = [I - K(k) \cdot Z^T(k)] H(k-1) / \rho \dots (41)$$

Since it becomes, in conformity with this serial calculation type algorithm, above-mentioned operation expression (7) - (15) is set up.

Moreover, if the fuel oil consumption f_i and the adhesion fuel quantity f_w which were computed by the 1st fuel-oil-consumption computing element A6 as what has an error in these presumed model parameters P and R are used when presuming the model parameters P and R using the above-mentioned (7) - (15) formula, since the model parameters P and R will be presumed in the form included to a part for the error, it is not desirable. Then, in this example, it sets in the identification vessel A7. So that the presumed model parameters P and R can update the model parameters P and R serially as the right thing. The 2nd fuel-oil-consumption computing element A9 which computes fuel oil consumption f_{ig} and the adhesion fuel quantity f_{wg} as what does not have an error in the model parameters P and R namely, using the fuel quantity f_{cr} in a target cylinder computed by the fuel quantity computing element A3 in a target cylinder as it is formed. It is made to input this calculation result into the identification machine A7 as the model parameter P and a false value for R presumption.

In the above, although the control law for fuel-oil-consumption control of this example was explained, it explains along with the flow chart which shows the fuel-injection control processing actually performed by the electronic control circuit 30 in realization of this control law next in a view 4.

This fuel-injection control processing is the processing of an internal combustion engine 2 by which after [starting] repeat execution is carried out, and sets initial value as the various parameters with which processing is started and which are not rich, perform Step 100 - Step 120, and are used for control. That is, processing of initialization is performed in the procedure of setting initial value P_0 and R_0 as the value of the model parameters P and R at Step 110 which sets initial value 0 as the adhesion fuel quantity f_w and the false adhesion fuel quantity f_{wg} , and follows them in Step 100 first, and setting initial value h_{11} o- h_{22} as the parameters h_{11} - h_{22} used for presumption of the model parameters P and R at Step 120 which continues further.

Next, in Step 130, the pressure-of-induction-pipe force P_m , rotational speed N_e , the cooling water temperature T_w , an intake-air temperature T_a , and a fuel-air ratio λ are measured based on the output signal from each above-mentioned sensor. And at continuing Step 140, it is based on the measured pressure-of-induction-pipe force P_m and rotational speed N_e of an internal combustion engine 2. Perform processing as a target air fuel ratio controller A2 which sets up target fuel-air-ratio λ_{bdr} according to the load of an internal combustion engine 2, and it shifts to continuing Step 150. Based on the pressure-of-induction-pipe force P_m , rotational speed N_e , and an intake-air temperature T_a , processing as an inflow air-content presumption machine A1 in a cylinder which computes the inflow air content m_c in a cylinder using above-mentioned (3) formulas or the above-mentioned map set up beforehand is performed.

By moreover, the thing multiplied by the fuel-air ratio λ measured at this computed inflow fuel quantity m_c in a cylinder and Step 130 at continuing Step 160 Perform processing as an inflow fuel quantity presumption machine A8 in a cylinder which computes the inflow air content f_c in a cylinder $\{=m_c(k) \cdot \lambda(k)\}$, and it shifts to the **** step 170. By multiplying by the inflow air content m_c in a cylinder calculated the account of a top, and target fuel-air-ratio λ_{bdr} set up at Step 140, processing as a fuel quantity computing element A3 in a target cylinder which computes the fuel quantity f_{cr} in a target cylinder is performed. And at continuing Step 180, processing as an amount computing

element A4 of target fuel amendments which computes amount of fuel amendments Δf_c using above-mentioned (4) formulas or the above-mentioned map set up beforehand is performed based on the pressure-of-induction-pipe force P_m (k-1) and the model parameters P and R for which it asked when the processing concerned was performed the pressure-of-induction-pipe force P_m searched for at Step 130, and last time.

Next, in continuing Steps 190-210, when the processing concerned is performed last time, based on the parameters h_{11} - h_{22} for which it asked at the below-mentioned step 200, Step 230, and Step 260, the false fuel oil consumption f_{ig} , and the false adhesion fuel quantity f_{wg} , processing as an identification machine A7 in which the model parameters P and R are presumed using above-mentioned operation expression (7) - (15) is performed. Namely, in Step 190, k_1 and k_2 are first calculated using (above-mentioned 10) and above-mentioned (11) formulas. k_1 and k_2 which calculated h_{11} - h_{22} using the above-mentioned (12) - (15) formula at continuing Step 200, and were calculated at Step 190 by Step 210 which continues further, The model parameters P and R are presumed in the procedure of computing the model parameters P and R using the above-mentioned (7) - (9) formula based on the inflow fuel quantity f_c in a cylinder calculated at Step 160, and the false fuel oil consumption f_{ig} and the false adhesion fuel quantity f_{wg} which were calculated last time.

Thus, if the model parameters P and R are presumed, it will shift to continuing Step 220. These computed model parameters P and R and the fuel quantity f_{cr} in a target cylinder calculated at Step 170, the [the amount computing element A4 of target fuel amendments which computes fuel oil consumption f_i using the above-mentioned (6) formulas based on amount of fuel amendments Δf_{cr} calculated at Step 180, and the adhesion fuel quantity f_w calculated last time at the below-mentioned step 250, subtractor A5, and] -- processing as a 1 fuel-oil-consumption computing element A6 is performed

Moreover, at continuing Step 230, processing as the 2nd fuel-oil-consumption computing element A9 which computes the false fuel oil consumption f_{ig} using the above-mentioned (17) formulas based on the model parameters P and R for which it asked at Step 210, the fuel quantity f_{cr} in a target cylinder calculated at Step 170, and the false adhesion fuel quantity f_{wg} calculated last time at the below-mentioned step 250 is performed.

And at continuing Step 240, by the fuel-injection timing determined based on the detecting signal from the above-mentioned crank angle sensor 24, a fuel injection valve 32 is opened according to the injection quantity f_i calculated at Step 220, and fuel injection is performed.

Thus, once fuel injection is performed at Step 240 and the fuel supply to an internal combustion engine 2 is completed, it will shift to continuing Step 250 and the adhesion fuel quantity f_w will be updated based on the fuel oil consumption f_i which actually performed fuel injection at Step 240, the last adhesion fuel quantity f_w used for calculation of this fuel oil consumption f_i , and the model parameters P and R for which it asked at Step 210, using the above-mentioned (1) formula as it is.

Moreover, at continuing Step 260, based on the false fuel oil consumption f_{ig} calculated at Step 230, the last false adhesion fuel quantity f_{wg} used for calculation of this false fuel oil consumption f_{ig} , and the model parameters P and R for which it asked at Step 210, the adhesion fuel quantity f_{wg} is updated using the above-mentioned (16) formulas, and it shifts to Step 130 again.

the control error which originated in the model error produced by with-time change of an internal combustion engine 2 since it presumed serially that the model parameters P and R explained above with the identification vessel A7 with the fuel-oil-consumption control unit of this example and was made to feed back to the operation expression for fuel-oil-consumption calculation -- good -- an amendment -- things are made moreover, the fuel quantity f_{cr} in a target cylinder which computes control error Δf_{cr} by this by the amount computing element A4 of target fuel amendments, and serves as control objectives even if an error arises in these presumed model parameters P and R at the time of transient operation of an internal combustion engine 2 etc. -- an amendment -- since it is made like, the fuel oil consumption from a fuel injection valve 32 serves as a value corresponding to the actual fuel behavior of an internal combustion engine 2, and can perform fuel-oil-consumption control with a sufficient precision

Moreover, in this example, since what is necessary is just to design a control law based on the fuel behavior model of (1) which simplified more the fuel behavior model described by the fuel behavior model of the control unit proposed by Japanese Patent Application No. No. 189889 [62 to] etc., the above-mentioned (21), and (22) formulas, and (2) formulas, and a design becomes easy and the operation expression for fuel-injection control moreover also becomes easy, the operation time for control can be shortened. [i.e.,]

Although the above-mentioned example explained here as what performs presumption of amount of target fuel amendments Δf_{cr} based on the variation of the pressure-of-induction-pipe force P_m using (4) formulas, you may make it presume amount of target fuel amendments Δf_{cr} like the following formula (42) from the variation of the inflow air content m_c in a cylinder computed, for example based on the operational status of an internal combustion

$$\delta f_{cr}(k) = \alpha \cdot \frac{P}{1-R} \{m_c(k) - m_c(k-1)\} \dots (42)$$

engine 2.

Moreover, you may make it presume amount of target fuel amendments δf_{cr} like the following formula (43) from the variation of the fuel oil consumption f_i computed based on the operational status of an internal combustion engine 2.

$$\delta f_{cr}(k) = \alpha \cdot \frac{P}{1-R} \{f_i(k) - f_i(k-1)\} \dots (43)$$

Moreover, although it constituted from an above-mentioned example paying attention to the bird clapper so greatly that the model parameters P and R change [control error δf_{cr}] and the adhesion fuel to inlet-pipe 4 wall surface increases so that amount of target fuel amendments δf_{cr} might be presumed by making $\alpha \cdot P/(1-R)$ into a proportionality constant. You may make it presume amount of target fuel amendments δf_{cr} like the following formula (44), using the adhesion fuel quantity f_w calculated instead of this proportionality-constant $\alpha \cdot P/(1-R)$ in order to compute fuel oil consumption f_i as it is.

$$\delta f_{cr}(k) = \alpha \cdot f_w \{P_m(k) - P_m(k-1)\}$$

-- (44)

Furthermore, although the identification machine A7 was used in the above-mentioned example in order to presume the model parameters P and R , it is not necessary to necessarily use the above identification machines for presumption of these model parameters P and R , and you may make it presume the model parameters P and R using the function or map showing the operational status of an internal combustion engine 2 of parameters (rotational speed N_e , pressure-of-induction-pipe force, cooling water temperature T_w , etc.).

Furthermore, although it explained as it is in the above-mentioned example as a thing using the fuel-air ratio λ detected by the fuel-air-ratio sensor 19 when presuming the inflow fuel quantity f_c in a cylinder, you may make it presume the inflow fuel quantity f_c in a cylinder from the fuel-air-ratio sensor 19 to a detecting signal, after amending such delay according to the flow delay of exhaust air by the exhaust air system, the detection delay of the fuel-air-ratio sensor 19, etc., since delay arose.

Moreover, although it constituted from an above-mentioned example so that the various operational status of an internal combustion engine 2 might be serially measured to the degree of fuel injection in Step 130, you may make it operate the cooling water temperature T_w , an intake-air temperature T_a , etc. on a curtailed schedule if needed about a variable with a slow change speed, for example.

Moreover, although it constituted from an above-mentioned example so that processing of Step 130 - Step 260 might be performed for every cycle of an internal combustion engine 2 synchronizing with the fuel injection of an internal combustion engine 2. Presumed processing of the model parameter of Step 190 - Step 210, presumed processing of the adhesion fuel quantity f_w of Step 250, And about other processings, it does not synchronize with rotation of an internal combustion engine 2, but may be made to perform, as long as it is made to perform for every cycle of an internal combustion engine 2 about presumed processing of the false adhesion fuel quantity f_{wg} of Step 260 repeatedly.

[Effect of the Invention]

As explained above, while presuming the model parameter of a fuel behavior model serially, updating a fuel behavior model and computing fuel oil consumption according to the updated fuel behavior model, with the fuel-oil-consumption control unit of the internal combustion engine of this invention, the fuel quantity in a target cylinder amended as control objectives by the control error produced at the time of transient operation of an internal combustion engine is used at the time of fuel-oil-consumption calculation. consequently, the control error resulting from the model error produced by with-time change of an internal combustion engine -- good -- an amendment -- while things are made, even if an error arises in this presumed model parameter at the time of transient operation of an internal combustion engine etc., fuel oil consumption can be controlled to the value corresponding to the actual fuel behavior of an internal combustion engine, and the control precision of an air-fuel ratio can be improved. Moreover, since fuel-oil-consumption control of an internal combustion engine can be performed with a sufficient precision by the control law set up in this invention in conformity with the fuel behavior model which made the state variable adhesion fuel quantity to an inlet-pipe wall surface. Compared with the equipment which performs fuel-oil-consumption control in conformity with the fuel behavior model which made the state variable inlet-pipe wall surface adhesion fuel quantity proposed by Japanese Patent Application No. No. 189889 [62 to] etc., and evaporation fuel quantity within an inlet pipe, the various operation expression used for control can be simplified, and the operation time for fuel-oil-

consumption control can be shortened.

[Translation done.]

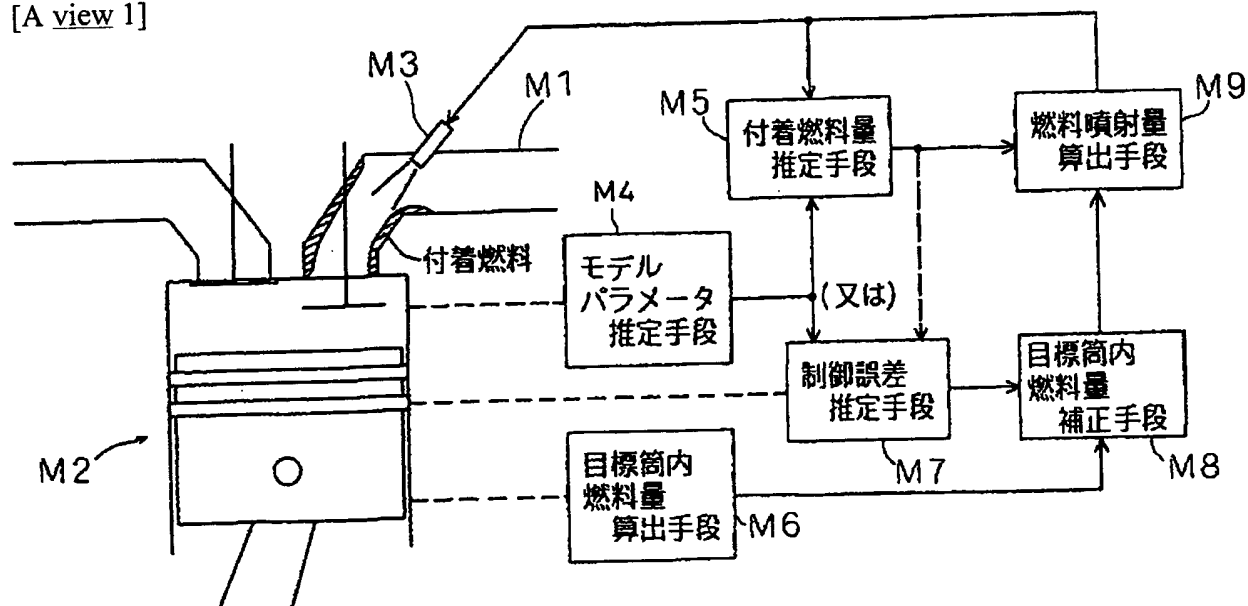
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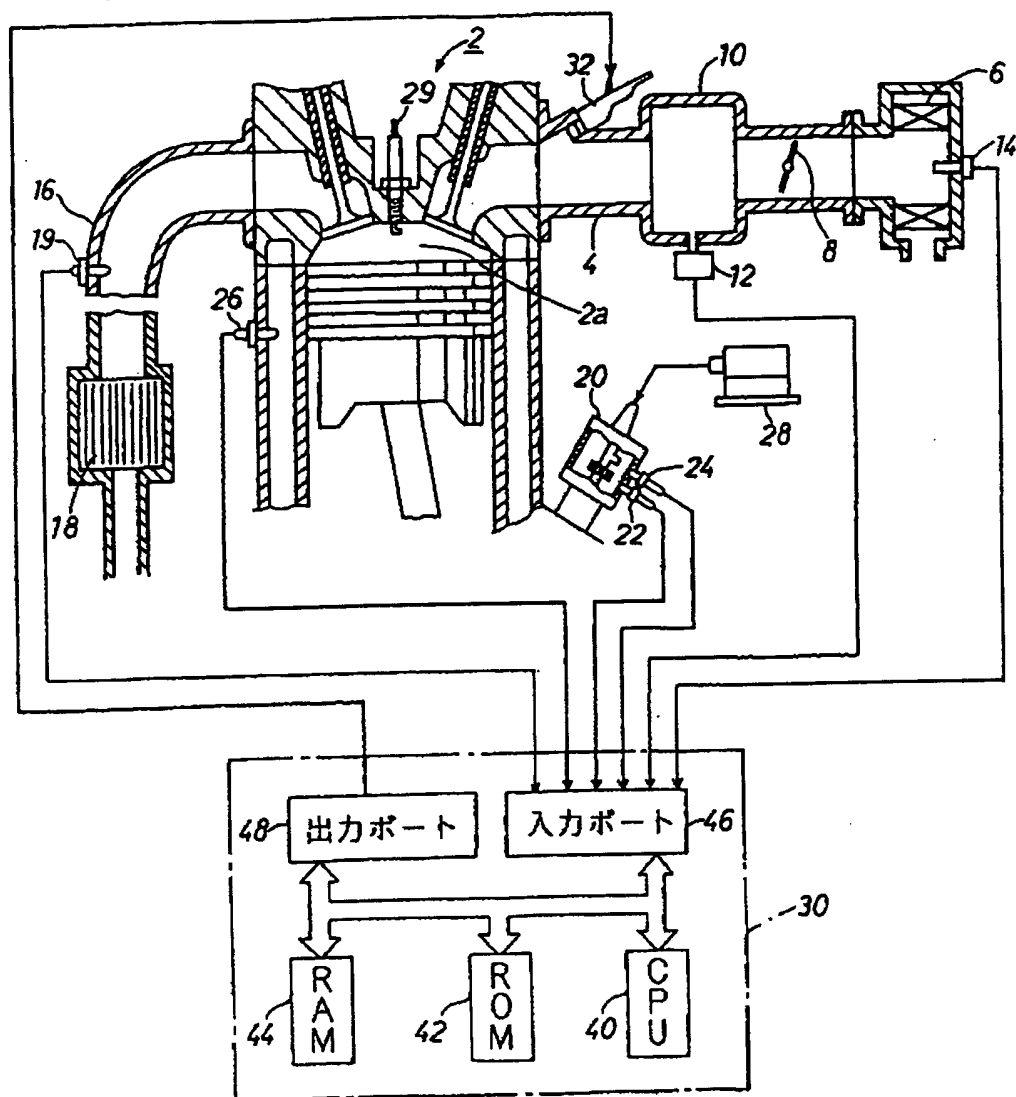
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DRAWINGS

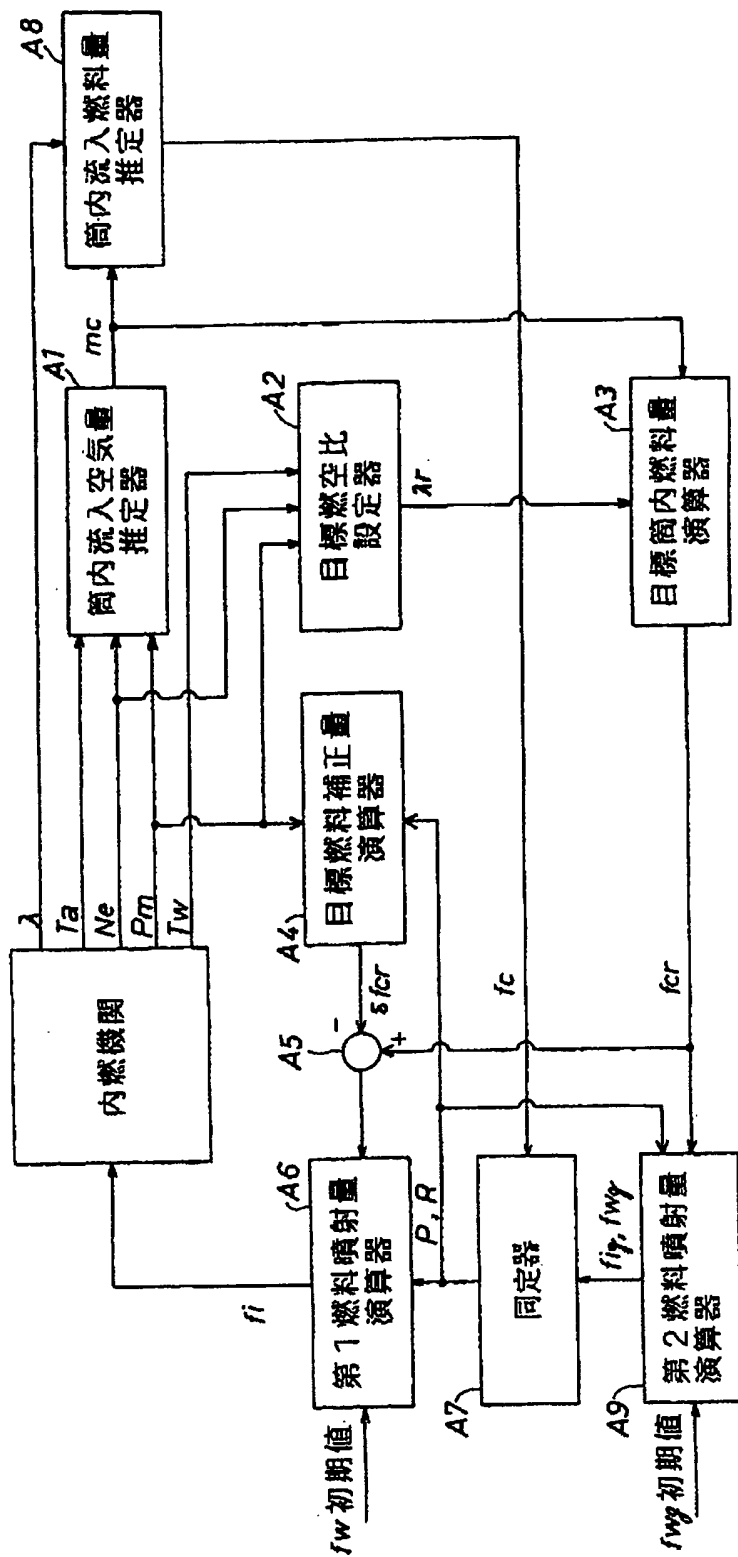
[A view 1]



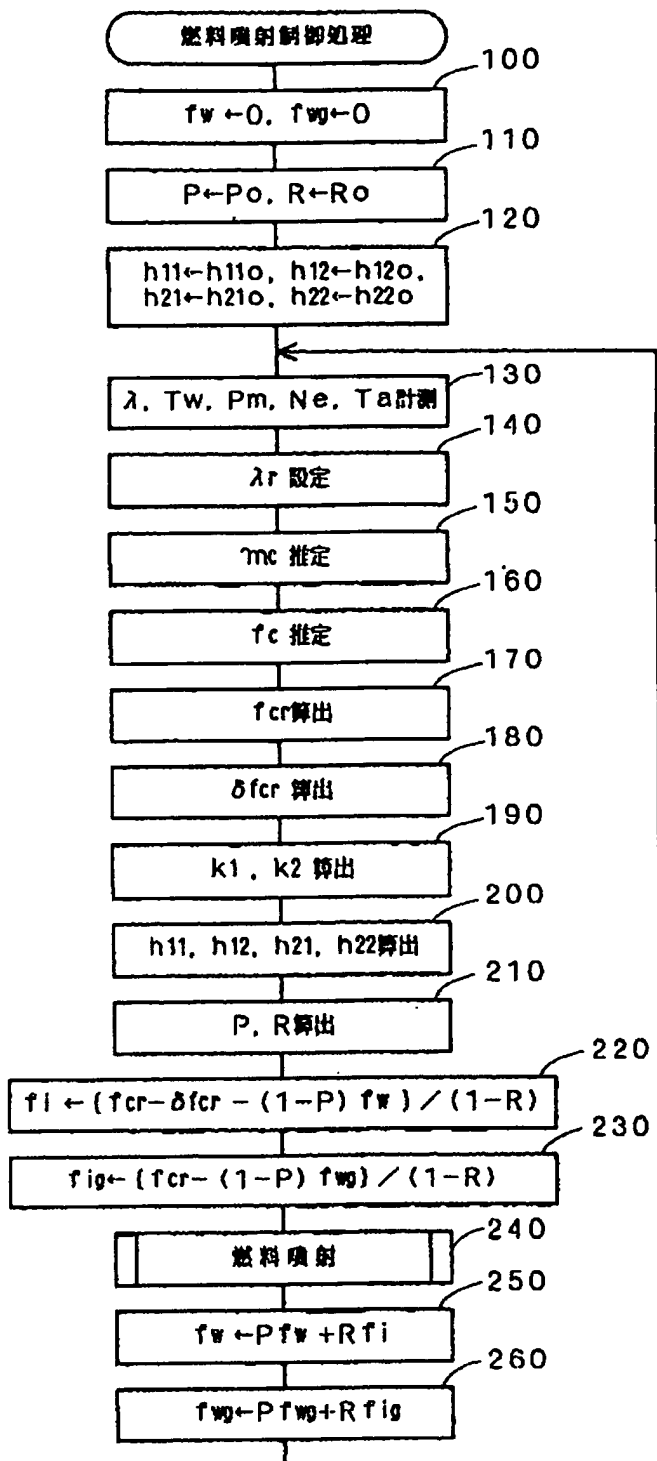
[A view 2]



[A view 3]



[A view 4]





PATENT ABSTRACTS OF JAPAN

(11) Publication number: **03018640 A**(43) Date of publication of application: **28.01.91**

(51) Int. Cl.

F02D 41/04
F02D 41/34
(21) Application number: **01153175**(71) Applicant: **TOYOTA MOTOR CORP**(22) Date of filing: **15.06.89**(72) Inventor: **OHATA AKIRA**(54) **INJECTION QUANTITY CONTROL DEVICE FOR
INTERNAL COMBUSTION ENGINE**

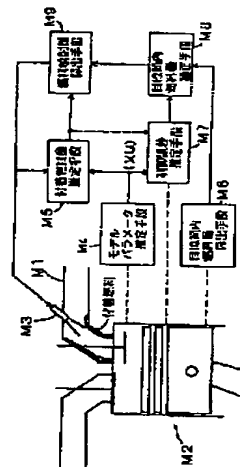
injection valve M3. The control accuracy of the air fuel ratio can be thus improved.

(57) Abstract:

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PURPOSE: To improve the fuel accuracy of the air-fuel ratio by enumerating the fuel injection quantity by the fuel behavior model renewed in succession as well as enumerating the fuel injection quantity on the basis of the target in-cylinder fuel quantity corrected by the control error at the time of transient operation.

CONSTITUTION: An estimating means M4 estimates the parameter of the fuel behavior model on the basis of the operating state of an internal combustion engine M2 so as to renew the fuel behavior model for control, and following this, an estimating means M5 estimates the fuel adhered to the wall surface of an intake pipe M1. An estimating means M7 estimates the estimation error of the in-cylinder fuel quantity from the estimated result of the estimating means M4, M5 and the transient operating state of the internal combustion engine M2. On the basis of the control error, a correcting means M8 corrects the target in-cylinder fuel quantity enumerated at an enumerating means M9 according to the operating state, and on the basis of these, the enumerating means M9 enumerates the fuel injection quantity from a fuel



(19)日本国特許庁 (J P)

(12) 特 許 公 報 (B 2)

(11)特許番号

第2754744号

(45)発行日 平成10年(1998) 5月20日

(24)登録日 平成10年(1998) 3月6日

(51)Int.Cl. ⁵	識別記号	F I	
F 0 2 D 41/04	3 3 0	F 0 2 D 41/04	3 3 0 B
41/14	3 1 0	41/14	3 1 0 L

請求項の数1 (全 13 頁)

(21)出願番号	特願平1-153175
(22)出願日	平成1年(1989) 6月15日
(65)公開番号	特開平3-18640
(43)公開日	平成3年(1991) 1月28日
審査請求日	平成7年(1995) 8月23日

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	特開 昭59-208143 (J P, A)
	特開 昭59-46353 (J P, A)

最終頁に続く

(54)【発明の名称】 内燃機関の燃料噴射量制御装置

(57)【特許請求の範囲】

【請求項1】吸気管壁面への付着燃料量を状態変数として内燃機関における燃料挙動を記述した燃料挙動モデルに則って燃料噴射弁からの燃料噴射量を制御する内燃機関の燃料噴射量制御装置であって、
内燃機関の運転状態に基づき上記燃料挙動モデルのモデルパラメータを推定し、該燃料挙動モデルを更新するモデルパラメータ推定手段と、
上記燃料噴射弁からの燃料噴射量に基づき、上記更新された燃料挙動モデルに従い、吸気管壁面への付着燃料量を推定する付着燃料量推定手段と、
内燃機関の運転状態に応じて、内燃機関のシリンダ内に供給すべき目標筒内燃料量を算出する目標筒内燃料量算出手段と、
上記モデルパラメータ推定手段又は上記付着燃料量推定

手段の推定結果と、内燃機関の過渡運転状態とに基づき、筒内燃料量の制御誤差を推定する制御誤差推定手段と、
該推定された制御誤差に基づき上記目標筒内燃料量を補正する目標筒内燃料量補正手段と、
該目標筒内燃料量補正手段の補正結果と上記付着燃料推定手段の推定結果とに基づき、上記更新された燃料挙動モデルに従い上記燃料噴射弁からの燃料噴射量を算出する燃料噴射量算出手段と、
を備えたことを特徴とする内燃機関の燃料噴射量制御装置。

【発明の詳細な説明】

〔産業上の利用分野〕

本発明は、内燃機関における燃料挙動を記述した燃料挙動モデルに則って燃料噴射量を制御する内燃機関の燃

料噴射量制御装置に関する。

〔従来の技術〕

従来より、内燃機関に供給される燃料混合気の空燃比が目標空燃比になるように燃料噴射弁からの燃料噴射量を制御する燃料噴射量制御装置の一つとして、例えば特開昭59-196930号公報に記載の如く、内燃機関の回転速度と吸入空気量とから求められる基本燃料噴射量を補正する補正値を制御入力、空燃比センサを用いて検出される空燃比の実測値を制御出力とし、該制御入力と制御出力との間に線形な近似が成り立つものとして同定を行い、内燃機関の動的な振舞いを記述する数式モデルを求め、これに基づき設計された制御則により燃料噴射量を制御する、所謂線形制御理論に基づく制御装置が知られている。

しかし上記制御入力と制御出力との関係は本来非線形であり、上記のように単に線形近似により数式モデルを求めたのでは内燃機関の動的な振舞いを極めて狭い運転条件下でしか記述することができず、制御を良好に行なうには、例えば特開昭59-7751号公報に記載の如く、線形近似が成り立つとみなし得る複数の運転領域毎に数式モデルを設定し、これに基づき各運転領域毎に制御則を決定しなければならなかった。このため従来では、制御則を内燃機関の各運転領域毎に切り替えなければならず、制御が煩雑になるといった問題があった。また各運転領域の境界点では制御則の切り替えのために制御が不安定になるといった問題もある。

そこで本願出願人は、特願昭62-189889号、特願昭62-189891号等により、吸気管壁面への付着燃料量と吸気管内での蒸発燃料量とを状態変数として内燃機関における燃料挙動を記述した燃料挙動モデルに基づき、非線形補償された制御則を決定することで、上記のように制御則を切り替えることなく（即ち一つの制御則で）燃料噴射量制御を実行できる燃料噴射量制御装置を提案した。

〔発明が解決しようとする課題〕

しかし上記燃料挙動モデルによっても内燃機関の燃料挙動を完全に記述することは難しく、実際には、内燃機関の過渡運転、燃料噴射系の経時的変化等によってモデルに誤差が生ずることがある。そしてこのようなモデル誤差が生ずると、これに基づく制御則が内燃機関と対応しなくなり、空燃比の制御精度が低下するといった問題が発生する。

そこで本発明は、燃料挙動モデルのモデル誤差に伴う制御誤差を精度よく補正することのできる内燃機関の燃料噴射量制御装置を提供することを目的としてなされた。

〔問題点を解決するための手段〕

即ち上記目的を達するためになされた本発明の構成は、第1図に例示する如く、

吸気管M1壁面への付着燃料量を状態変数として内燃機関M2における燃料挙動を記述した燃料挙動モデルに則

て燃料噴射弁M3からの燃料噴射量を制御する内燃機関の燃料噴射量制御装置であって、

内燃機関M2の運転状態に基づき上記燃料挙動モデルのモデルパラメータを推定し、該燃料挙動モデルを更新するモデルパラメータ推定手段M4と、

上記燃料噴射弁M3からの燃料噴射量に基づき、上記更新された燃料挙動モデルに従い、吸気管M1壁面への付着燃料量を推定する付着燃料量推定手段M5と、

内燃機関M2の運転状態に応じて、内燃機関M2のシリンダ内に供給すべき目標筒内燃料量を算出する目標筒内燃料量算出手段M6と、

上記モデルパラメータ推定手段M4又は上記付着燃料量推定手段M5の推定結果と、内燃機関M2の過渡運転状態とに基づき、筒内燃料量の制御誤差を推定する制御誤差推定手段M7と、

該推定された制御誤差に基づき上記目標筒内燃料量を補正する目標筒内燃料量補正手段M8と、

該目標筒内燃料量補正手段M8の補正結果と上記付着燃料量推定手段M5の推定結果とに基づき、上記更新された燃料挙動モデルに従い上記燃料噴射弁M3からの燃料噴射量を算出する燃料噴射量算出手段M9と、

を備えたことを特徴とする内燃機関の燃料噴射量制御装置を要旨としている。

〔作用〕

以上のように構成された本発明の燃料噴射量制御装置においては、モデルパラメータ推定手段M4が、内燃機関M2の運転状態に基づき燃料挙動モデルのモデルパラメータを推定して制御に用いる燃料挙動モデルを更新し、付着燃料量推定手段M5が、その更新された燃料挙動モデルに従い吸気管M1壁面への付着燃料量を推定する。また目標筒内燃料量算出手段M6が、内燃機関M2の運転状態に応じて制御目標となる目標筒内燃料量を算出し、制御誤差推定手段M7が、モデルパラメータ推定手段M4又は上記付着燃料量推定手段M5の推定結果と、内燃機関M2の過渡運転状態とに基づき筒内燃料量の制御誤差を推定する。すると目標筒内燃料量補正手段M8が、この推定された制御誤差に基づき目標筒内燃料量を補正し、燃料噴射量算出手段M9が、この補正された目標筒内燃料量と付着燃料量推定手段M5で推定された壁面付着燃料量とに基づき、燃料噴射弁M3からの燃料噴射量を算出する。

即ち本発明は、内燃機関M2の過渡運転時に生ずるモデル誤差に起因した制御誤差を、モデルパラメータ推定手段M4で推定されたモデルパラメータ又は付着燃料量推定手段M5で推定された付着燃料量と内燃機関M2の過渡運転状態とに基づき推定し、その推定結果により制御目標となる目標筒内燃料量を補正して、燃料噴射量を算出する。この結果、燃料噴射量は予め制御誤差を加味した値として設定されることとなり、内燃機関M2が過渡運転されても制御誤差を生ずることなく燃料噴射量制御を実行することが可能となる。

また内燃機関M2の経時変化によって生ずるモデル誤差に起因した制御誤差は、モデルパラメータ推定手段M4がモデルパラメータを推定して制御則を決定する燃料挙動モデルを更新することで解消され、これによっても制御精度を向上できる。

〔実施例〕

以下に本発明の実施例を図面と共に説明する。

まず第2図は本発明が適用された内燃機関2及びその周辺装置の構成を表す概略構成図である。

図に示す如く内燃機関2の吸気管4には、吸入空気を浄化するエアクリーナ6、吸入空気量を制御するスロットルバルブ8、吸気の脈動を抑えるサージタンク10、サージタンク10内の圧力（吸気管圧力） P_m を検出する吸気圧センサ12、及び吸気温度 T_a を検出する吸気温センサ14が備えられ、排気管16には、排気を浄化する三元触媒18、及び三元触媒18より上流で排気中の酸素成分から内燃機関2のシリンダ2a内に流入した燃料混合気の燃空比 λ （空燃比A/Fの逆数）を検出する燃空比センサ19が備えられている。

また当該内燃機関2には、その運転状態を検出するためのセンサとして、上記吸気圧センサ12、吸気温センサ14及び燃空比センサ19の他、ディストリビュータ20の回転から内燃機関2の回転速度 N_e を検出するための回転速度センサ22、同じくディストリビュータ20の回転から内燃機関2への燃料噴射タイミングを検出するためのクランク角センサ24、及び内燃機関2の冷却水温 T_w を検出する水温センサ26等が備えられている。尚ディストリビュータ20はイグニタ28からの高電圧を所定の点火タイミングで点火プラグ29に印加するためのものである。

そして上記各センサからの検出信号は、マイクロコンピュータを中心とした論理演算回路として構成された電

$$f_c(k) = (1-P) f_w(k) + (1-R) f_i(k) \quad \dots (2)$$

（但し、 f_i ：燃料噴射量、 f_c ：筒内燃料量、 P, R ：定数）

第3図に示すように、本実施例では、まず吸気圧センサ12、吸気温センサ14及び回転速度センサ22からの検出信号により得られる吸気管圧力 P_m 、吸気温 T_a 及び回転速度 N_e が筒内流入空気量推定器A1に入力される。筒内流入空気量推定器A1は、吸気行程時に内燃機関2のシリンダ2aに流入する空気量（筒内吸入空気量） m_c を推定するためのもので、上記各入力された吸気管圧力 P_m 、吸気温 T_a 及び回転速度 N_e に基づき、次式（3）

$$m_c = \{ \beta_x(N_e) \cdot P_m - \beta_y(N_e) \} / T_a \quad \dots (3)$$

（但し、 $\beta_x(N_e)$ 、 $\beta_y(N_e)$ ：回転速度 N_e の関数）を用いて筒内吸入空気量 m_c を推定する。

また次に上記吸気管圧力 P_m 及び回転速度 N_e の各データは、水温センサ26からの検出信号により得られる冷却水温 T_w と共に目標燃空比設定器A2にも入力される。目標燃空比設定器A2は、内燃機関2に供給すべき燃料混合気の燃空比（目標燃空比） λ_r を設定するためのもので、上

子制御回路30に入力され、燃料噴射弁32を駆動して燃料噴射弁32からの燃料噴射量を制御するのに用いられる。

即ち電子制御回路30は、予め設定された制御プログラムに従って燃料噴射量制御のための演算処理を実行するCPU40、CPU40で演算処理を実行するのに必要な制御プログラムや初期データが予め記録されたROM42、同じくCPU40で演算処理を実行するのに用いられるデータが一時的に読み書きされるRAM44、上記各センサからの検出信号を入力するための入力ポート46、及びCPU40での演算結果に応じて燃料噴射弁32に駆動信号を出力するための出力ポート48、等から構成され、内燃機関2のシリンダ2a内に流入する燃料混合気の燃空比 λ が所定の目標燃空比 λ_r になるように燃料噴射弁32からの燃料噴射量を制御する。

次にこの電子制御回路30で実行される燃料噴射量制御の制御則を第3図に示すブロック図に基づいて説明する。

尚第3図は、当該実施例の制御則を示す図であって、ハード的な構成を示すものではなく、実際の燃料噴射量制御は後述の第4図のフローチャートに示した一連の制御プログラムの実行により実現される。

またこの制御則は、後述するように、吸気管4壁面への付着燃料量 f_w を状態変数として内燃機関2のシリンダ2a内に流入する燃料の挙動を記述した次式（1）及び（2）に示す燃料挙動モデルに基づき、内燃機関2の1サイクル毎に燃料噴射量の算出を行なうように設計されたものであり、以下の説明において現時点の値には添え字（ k ）を、1サイクル前の値には添え字（ $k-1$ ）を付して表わすものとする。

$$f_w(k+1) = P \cdot f_w(k) + R \cdot f_i(k) \quad \dots (1)$$

$$f_c(k) = (1-P) f_w(k) + (1-R) f_i(k) \quad \dots (2)$$

記各入力データに基づき内燃機関2の負荷運転状態、暖機運転状態等を求め、内燃機関2が加速時等の高負荷運転状態にあるときや冷却水温 T_w が低く内燃機関2を暖機運転する必要のあるとき等には目標燃空比 λ_r を空気過剰率が1となる理論空燃比より燃料分が多いリッチ側の値に設定し、内燃機関2が減速時等の軽負荷運転状態にあるときには目標燃空比 λ_r を理論空燃比より燃料分の少ないリーン側の値に設定し、それ以外の通常運転時には目標燃空比 λ_r を理論空燃比に対応した値に設定する。

そしてこのように筒内流入空気量推定器A1で推定された筒内流入空気量 m_c 及び目標燃空比設定器A2で設定された目標燃空比 λ_r は、目標筒内燃料量演算器A3に入力され、制御目標となる目標筒内燃料量 f_{cr} に変換される。即ちこの目標筒内燃料量演算器A3は、前述の目標筒内燃料量算出手段M6に相当するもので、筒内流入空気量 m_c と目標燃空比 λ_r とを乗ずることにより目標筒内燃料量 f_{cr} （ $=m_c \cdot \lambda_r$ ）を算出する。

また次に吸気管圧力 P_m は目標燃料補正量演算器A4にも入力される。目標燃料補正量演算器A4は、内燃機関2の過渡運転時に生ずる燃料挙動モデルのモデル誤差に起因した筒内燃料量の制御誤差を、目標筒内燃料量演算器A3で算出された目標筒内燃料量 f_{cr} に対する補正量として

$$\delta f_{cr}(k) = \alpha \cdot \frac{P}{1-R} \{P_m(k) - P_m(k-1)\} \quad \dots (4)$$

を用いて燃料補正量 δf_{cr} を算出する。尚この目標燃料補正量演算器A4は前述の制御誤差推定手段M7に相当する。

そしてこの算出された燃料補正量 δf_{cr} は、目標筒内燃料量演算器A3で算出された目標筒内燃料量 f_{cr} と共に目標筒内燃料量補正手段M8としての減算器A5に入力され、減算器A5で、目標筒内燃料量 f_{cr} から燃料補正量 δf_{cr} を減じて、目標筒内燃料量 f_c を補正するのに使用される。

次に減算器A5の減算結果、即ち補正目標筒内燃料量 $f_{crh} (= f_{cr} - \delta f_{cr})$ は、後述の同定器A7で求められた燃料挙動モデルのモデルパラメータ P, R と共に、第1

$$f_i = \frac{f_{crh} - (1-P) f_w}{1-R} \quad \dots (6)$$

(P, R : 同定器A7で求めたモデルパラメータ)を用いて、燃料噴射弁32から次に燃料燃料噴射を行なうための燃料噴射量 f_i を算出する。

尚、この第1燃料噴射量演算器A6において、制御開始時の付着燃料量 f_w を推定する際の前回の付着燃料量推定値には、予め設定された初期値(本実施例では0)が使用される。

次に同定器A7は、前述のモデルパラメータ推定手段M4に相当し、上記(1)及び(2)式で記述された燃料挙動モデルのモデルパラメータ P, R を推定するためのもの

$$E(k) = f_c(k) - \{1-P(k-1)\} f_{wg}(k) + \{1-R(k-1)\} f_{ig}(k) \quad \dots (9)$$

$$k_1(k) = \{h_{11}(k-1) f_{wg}(k) + h_{12}(k-1) f_{ig}(k)\} / [\rho + h_{11}(k-1) f_{wg}^2(k) + \{h_{21}(k-1) + h_{12}(k-1)\} f_{wg}(k) f_{ig}(k) + h_{22}(k-1) f_{ig}^2(k)] \quad \dots (10)$$

$$k_2(k) = \{h_{21}(k-1) f_{wg}(k) + h_{22}(k-1) f_{ig}(k)\} / [\rho + h_{11}(k-1) f_{wg}^2(k) + \{h_{21}(k-1) + h_{12}(k-1)\} f_{wg}(k) f_{ig}(k) + h_{22}(k-1) f_{ig}^2(k)] \quad \dots (11)$$

である。またこの(10)及び(11)式において、 ρ は後述するように予め設定された定数($0 < \rho \leq 1$)であり、 $h_{11}(k-1) \sim h_{22}(k-1)$ は次式(12)～(1

$$h_{11}(k) = [h_{11}(k-1) - k_1(k) \{h_{11}(k-1) f_{wg}(k) + h_{21}(k-1) f_{ig}(k)\}] / \rho \quad \dots (12)$$

$$h_{12}(k) = [h_{12}(k-1) - k_1(k) \{h_{12}(k-1) f_{wg}(k)$$

算出するためのもので、後述の同定器A7で求められた燃料挙動モデルのモデルパラメータ(即ち上記(1)及び(2)式における定数) P, R と、吸気圧センサ12により検出される吸気管圧力 P_m の変化量と、定数 α とに基づき、次式(4)

燃料噴射量演算器A6に入力される。

第1燃料噴射量演算器A6は、前述の付着燃料量推定手段M5及び燃料噴射量算出手段M9に相当するもので、まず燃料噴射弁32からの燃料噴射毎に次式(5)を用いて、吸気管壁面4への付着燃料量 f_w を推定し、

$$f_w(k+1) = P \cdot f_w(k) + R \cdot f_i(k) \quad \dots (5)$$

(但し、 $f_i(k)$: 燃料噴射弁32からの燃料噴射量、 $f_w(k)$: 前回の推定値、 P, R : 同定器A7で求めたモデルパラメータ)

その推定結果 f_w と上記入力された補正目標筒内燃料量 f_{crh} とに基づき、次式(6)

で、筒内流入燃料量推定器A8で推定されたシリンダ2a内に実際に流入した燃料量(実筒内流入燃料量) f_c と第2燃料噴射量演算器A9で算出された疑似付着燃料量 f_{wg} 及び疑似燃料噴射量 f_{ig} に基づき、次式(7)及び(8)の如くモデルパラメータ P, R を推定する。

$$P(k) = P(k-1) - k_1(k) \cdot E(k) \quad \dots (7)$$

$$R(k) = R(k-1) - k_2(k) \cdot E(k) \quad \dots (8)$$

但し、上記(7)及び(8)式において、

5)を用いて前回(即ち1サイクル前)算出した値である。

$$+h22(k-1) \text{fig}(k) \} \} / \rho \quad \dots (13)$$

$$h21(k) = [h21(k-1) - k2(k) \{h11(k-1) \text{fwg}(k) + h21(k-1) \text{fig}(k) \} \} / \rho \quad \dots (14)$$

$$h22(k) = [h22(k-1) - k1(k) \{h12(k-1) \text{fwg}(k) + h22(k-1) \text{fig}(k) \} \} / \rho \quad \dots (15)$$

次に筒内流入燃料量推定器A8は、上述のようにシリンダ2a内に実際に流入した燃料量（実筒内流入燃料量） f_c を推定するためのもので、燃空比センサ19からの検出信号により得られる実燃空比 λ と、筒内流入空気量推定器A1で求められた筒内流入空気量 m_c とを乗ずること

で、実筒内流入燃料量 $f_c (= \lambda \cdot m_c)$ を推定する。

また第2燃料噴射量演算器A9は、モデルパラメータP、Rを推定する際に用いる燃料噴射量及び付着燃料量として、モデル誤差がないものとして算出した疑似燃料噴射

$$\text{fig} = \frac{f_{cr} - (1 - P) \text{fwg}}{1 - R} \quad \dots (17)$$

(P、R: 同定器A7で求めたモデルパラメータ) を用いて疑似燃料噴射量 fig を算出する。

尚この第1燃料噴射量演算器A9において、制御開始時の付着燃料量 fwg を推定する際の前回の付着燃料量推定値には、予め設定された初期値（本実施例では0）が使用される。

次に上記（1）及び（2）式で記述された燃料挙動モデル、及び該燃料挙動モデルに基づく上記制御則の設計方法について説明する。

まず内燃機関2のシリンダ2a内に流入する燃料量、即ち筒内燃料量 f_c は、燃料噴射弁32からの燃料噴射量 f_i と、吸気管4壁面への付着燃料量 fw と、吸気管4内部での蒸発燃料量 f_v とを用いて次式（18）のように記述することができる。

$$f_c = \alpha 1 \cdot f_i + \alpha 2 \cdot \text{fw} + \alpha 3 \cdot f_v \quad \dots (18)$$

即ち上記燃料量 f_c は、燃料噴射弁32からの噴射燃料の直接流入量 $\alpha 1 \cdot f_i$ と、その噴射燃料が付着した吸気管4からの間接流入量 $\alpha 2 \cdot \text{fw}$ と、噴射燃料或は壁面付着燃料の蒸発により吸気管4内部に存在する蒸発燃料の流入量 $\alpha 3 \cdot f_v$ との総和であると考えられること

$$\text{fw}(k+1) = (1 - \alpha 2) \cdot \text{fw}(k) + \alpha 4 \cdot f_i(k) - \alpha 5 \cdot V f_w(k) \quad \dots (19)$$

一方吸気管4内部での蒸発燃料量 f_v は、吸気行程時のシリンダ2a内への流入によって、内燃機関2の1サイクル毎にその一部 $\alpha 3$ が減少する他、燃料噴射量 f_i の一部 $\alpha 6$ が蒸発することによって増加し、更に上記付着

$$f_v(k+1) = (1 - \alpha 3) \cdot f_v(k) + \alpha 6 \cdot f_i(k) + \alpha 5 \cdot V f_w(k) \quad \dots (20)$$

従って上記（18）～（20）式において、 $(1 - \alpha 2)$ をP、 $(1 - \alpha 3)$ をQ、 $\alpha 4$ をR、 $\alpha 6$ をS、 $\alpha 5$ をDとして整理することにより、吸気筒壁面への付着燃料量と蒸発

量 fig 及び付着燃料量 fwg を設定するためのもので、第1燃料噴射量演算器A6と同様に、燃料噴射弁32からの燃料噴射毎に次式（16）を用いて、吸気管壁面4への疑似付着燃料量 fwg を推定し、

$$\text{fwg}(k+1) = P \cdot \text{fwg}(k) + R \cdot \text{fig}(k) \quad \dots (16)$$

その推定結果 fwg と目標筒内燃料量演算器A3で算出した目標筒内燃料量 f_{cr} とに基づき次式（17）

から、上式（18）のようにシリンダ2a内に流入する燃料量 f_c を記述することができる。

上式（18）において、燃料噴射量 f_i は燃料噴射弁32の開弁時間によって定まるので、吸気筒4壁面への付着燃料量 fw 及び吸気管4内での蒸発燃料量 f_v を知ることができれば、燃料量 f_c を予測することができる。

そこで次に上記付着燃料量 fw 及び蒸発燃料量 f_v について考える。

まず吸気管4壁面への付着燃料量 fw は、吸気行程時のシリンダ2a内への流入によって、吸気行程時にその一部 $\alpha 2$ が減少する他、吸気管4内部への蒸発によって減少し、内燃機関2の回転と同期して燃料噴射弁32から噴射される燃料噴射量 f_i の一部 $\alpha 4$ が付着することによって増加する。また内燃機関2の1サイクル当りの燃料蒸発量は、単位時間当りの燃料蒸発量（即ち燃料蒸発速度） $V f$ と内燃機関2の回転速度 N_e とから、 $\alpha 5 \cdot V f / N_e (= \alpha 5 \cdot V f_w, \alpha 5: \text{比例定数})$ として表すことができる。このため吸気管4壁面への付着燃料量 fw は次式（19）に示す如く記述できる。

燃料の燃料蒸発によって増加する。

このため吸気管4内の蒸発燃料量 f_v は、次式（20）に示す如く記述できる。

燃料量とを状態変数とし、内燃機関2の1サイクルをサンプリング周期として離散系で表現された次式（21）及び（22）の如き燃料挙動モデルが定まる。

$$\begin{bmatrix} f_w(k+1) \\ f_v(k+1) \end{bmatrix} = \begin{bmatrix} P & 0 \\ 0 & Q \end{bmatrix} \cdot \begin{bmatrix} f_w(k) \\ f_v(k) \end{bmatrix} + \begin{bmatrix} R \\ S \end{bmatrix} \cdot f_i(k) + \begin{bmatrix} -D \\ +D \end{bmatrix} \cdot V f_w(k) \quad \dots (21)$$

$$f_c(k) = [1 - P \quad 1 - Q] \begin{bmatrix} f_w(k) \\ f_v(k) \end{bmatrix} + (1 - R - S) f_i(k) \quad \dots (22)$$

このような燃料挙動モデルでは、各モデルパラメータ P, Q, R, S, D を周知の同定法により定めれば、内燃機関の定常運転時の燃料挙動を全運転領域ではほぼ正確に記述することができるようになる。しかし上記燃料挙動モデルにおいても、従来技術の項でも述べたように、内燃機関 2 の過渡運転または内燃機関 2 の経時的变化等によって実際の燃料挙動を正確に記述できなくなることがあり、この燃料挙動モデルをそのまま用いて制御則を設計しても良好な制御精度が得られない場合がある。

そこで本実施例では、上記 (21) 及び (22) 式で記述された燃料挙動モデルにおいて、付着燃料量 f_w 及び燃料噴射量 f_i に比べて著しく小さく、燃料挙動に大きな

影響を与えることのない蒸発燃料量 f_v 及び燃料蒸発量 $V f_w$ を無視して、上記 (1) 及び (2) 式の如く簡略化された燃料挙動モデルを作成し、この燃料挙動モデルに基づき、モデルの簡略化、内燃機関 2 の過渡運転、及び内燃機関 2 の経時的变化等によって生ずる制御誤差を補償し得るように制御則が設計されている。

即ちまず上記 (1) 及び (2) 式で記述された燃料挙動モデルに誤差がなければ、筒内燃料量 f_c を目標筒内燃料量 f_{cr} に制御するための燃料噴射量 f_i は、上記燃料挙動モデルの出力方程式 { (2) 式 } を変形することで、次式 (23) の如く求めることができる。

$$f_i = \frac{f_{cr} - (1 - P) f_w}{1 - R} \quad \dots (23)$$

しかし上記燃料挙動モデルには、モデルの簡略化、内燃機関 2 の過渡運転、及び内燃機関 2 の経時的变化等により誤差が生ずるので、この (23) 式をそのまま用いて制御すると制御誤差が発生する。

そこで本実施例では、上述したようにモデルパラメータ P, R を推定するための同定器 A7 を設け、この同定器 A7 によりモデルパラメータ P, R を逐次推定してゆき、この推定された最新のモデルパラメータ P, R を用いて燃料噴射量 f_i を算出するようにしている。

またこのように同定器 A7 によりモデルパラメータ P, R を推定して燃料噴射量 f_i を算出する場合、内燃機関 2 の定常運転時には、良好な燃料噴射制御を実行できるようになるのであるが、内燃機関 2 の運転状態が急変する過渡運転時には、内燃機関 2 の運転状態の検出遅れ等に

よってモデルパラメータの推定値 P, R に誤差が生じ、これによって制御誤差が発生する。このため本実施例では、更にこうした過渡運転時に生ずるモデル誤差に伴う制御誤差を補正するために、目標燃料補正量演算器 A4 及び減算器 A5 を設けて、目標筒内燃料量演算器 A3 で算出した目標筒内燃料量 f_{cr} を補正し、この補正された補正目標筒内燃料量 f_{crh} により燃料噴射量 f_i を算出するようにしている。

以下、こうしたモデル誤差補償のための目標燃料補正量演算器 A4 及び同定器 A7 の設計手順について説明する。

まず上記 (1) 及び (2) 式において、Z 変換を行ない系の伝達関数を求める。

上記 (1) 及び (2) を Z 変換すると、

$$Z f_w(Z) = P f_w(Z) + R f_i(Z) \quad \dots (24)$$

$$Z f_v(Z) = Q f_v(Z) + D f_w(Z) \quad \dots (25)$$

となる。また上式 (24) から $f_w(Z)$ は次式 (26)

$$f_w(Z) = \frac{R \cdot f_i(Z)}{Z - P} \quad \dots (26)$$

の如く記述できる。そこで上式 (26) を (25) 式に代入すると、

$$f_c(Z) = \frac{(1-R)Z + (R-P)}{Z - P} f_i(Z) \quad \dots (27)$$

となり、系の伝達関数が得られる。

一方、上記 (1) 及び (2) 式においては、過渡運転時に生ずるモデルパラメータ推定値 P, R の誤差を δ とす

$$f_w(k+1) = P \cdot f_w(k) + R \cdot f_i(k) - \delta(k) \quad \dots (28)$$

$$f_c(k) = (1-P) f_w(k) + (1-R) f_i(k) + \delta(k) \quad \dots (29)$$

上記と同様に、この (28) 及び (29) 式において Z 変換を行ない系の伝達関数を求めると、次式 (30) の如く

$$f_c(Z) = \frac{(1-R)Z + (R-P)}{Z - P} f_i(Z) + \frac{Z - 1}{Z - P} \delta(Z) \quad \dots (30)$$

次に上記 (27) 式で記述された系において、筒内燃料量 f_c を目標筒内燃料量 f_{cr} に制御するための燃料噴射

量 f_i は、逆伝達関数を用いると、次式 (31) の如くなる。

$$f_i(Z) = \frac{Z - P}{(1-R)Z + (R-P)} f_{cr}(Z) \quad \dots (31)$$

そしてこの (31) 式を上記 (30) 式に代入すると、モデル誤差 δ を考慮せず燃料噴射量を制御した場合の目標

値に対する伝達関数が次式 (32) の如く得られる。

$$f_c(Z) = f_{cr}(Z) + \frac{Z - 1}{Z - P} \delta(Z) \quad \dots (32)$$

従って、この (32) 式から、モデル誤差 δ による筒内燃料量 f_c の制御誤差 δf_{cr} は、次式 (33) の如く求ま

る。

$$\delta f_{cr}(Z) = \frac{Z - 1}{Z - P} \delta(Z) \quad \dots (33)$$

こうした制御誤差 δf_{cr} は、制御目標となる筒内燃料量を、目標筒内燃料量 f_{cr} から制御誤差 δf_{cr} 分の燃料量を減じた値（即ち上記減算器 A5 で算出される補正目標筒内燃料量） f_{crh} に変更することで解消できる。このため本実施例では、上記 (23) 式における目標筒内燃料量 f_{cr} を補正目標筒内燃料量 f_{crh} に変更することで、第 1 燃料噴射量演算器 A6 において燃料噴射弁 32 からの燃料噴射量 f_i を算出するために使用する前述の (6) 式が設定されている。

一方この制御誤差 δf_{cr} を決定することは困難であるが、実際の制御では、制御誤差 δf_{cr} は内燃機関 2 の過渡運転状態を表わすパラメータの関数として実験的にパターン化することができる。またこの制御誤差 δf_{cr} は、モデルパラメータ P, R が変化し、吸気管 4 壁面への付着燃料が増大する程大きくなる。そこで本実施例では、 $P/(1-R)$ が燃料噴射量 f_i が吸気管壁面に付着する程度を表わす指標となることから、制御誤差 δf_{cr} を、 $P/(1-R)$ に比例させ、且つ、内燃機関 2 の過渡

状態を表す吸気管圧力 P_m の変化量の関数として算出するように、制御誤差算出用の前述の演算式(4)を設定している。

次にモデルパラメータ P, R を推定する同定器A7は、指数荷重形最小二乗アルゴリズムに則ってモデルパラメータを推定するようにされている。尚こうしたパラメータ同定の手法については、中溝高好著「線形離散時間システムの同定手法-1」システムと制御, Vol. 25, No. 8, P476~P489, 1981年, 等に詳述されているので、詳細な説明

$$J = \sum_{i=0}^k \rho^{k-i} \cdot \{e(k)\}^2 \quad \dots (35)$$

{但し、 ρ は0から1の間に設定された値($1 < \rho \leq 0$)であり、過去値になるほど重みを小さくして推定値への寄与を減少させるためのForgetting Factorであ

は省略する。

即ち、最小二乗法によるパラメータ推定問題とは、燃料挙動モデルのモデル誤差 $e(k)$ を出力方程式{(2)式}を変形して次式(34)如く記述したときの、次式(35)の如き評価関数 J を最小にするモデルパラメータを求めることであり、

$$e(k) = f_c(k) - (1-P)f_w(k) - (1-R)f_i(k) \quad \dots (34)$$

る。}

このための逐次計算形アルゴリズムは、

$$\Theta(k) = [P(k) \quad R(k)]^T \quad \dots (36)$$

$$Z(k) = [f_w(k) \quad f_i(k)]^T \quad \dots (37)$$

$$y(k) = f_c(k) \quad \dots (38) \quad \text{としたとき、}$$

$$\Theta(k) = \Theta(k-1) + K(k) [y(k) - Z^T(k) \cdot \Theta(k-1)] \quad \dots (39)$$

$$K(k) = H(k-1) \cdot Z(k) [\rho + Z^T(k) \cdot H(k-1) \cdot Z(k)]^{-1} \quad \dots (40)$$

$$H(k) = [I - K(k) \cdot Z^T(k)] H(k-1) / \rho \quad \dots (41)$$

となるので、この逐次計算形アルゴリズムに則って、上述の演算式(7)~(15)が設定されている。

また上記(7)~(15)式を用いてモデルパラメータ P, R を推定する場合、この推定したモデルパラメータ P, R に誤差があるものとして第1燃料噴射量演算器A6で算出された燃料噴射量 f_i 及び付着燃料量 f_w を使用すると、その誤差分まで含めた形でモデルパラメータ P, R が推定されてしまうので好ましくない。そこで本実施例では、同定器A7においては、推定したモデルパラメータ P, R が正しいものとしてモデルパラメータ P, R を逐次更新できるように、目標筒内燃料量演算器A3で算出された目標筒内燃料量 f_{cr} をそのまま用いて(即ちモデルパラメータ P, R に誤差がないものとして)燃料噴射量 f_{ig} 及び付着燃料量 f_{wg} を算出する第2燃料噴射量演算器A9を設け、この算出結果をモデルパラメータ P, R 推定用の疑似値として、同定器A7に入力するようにしている。

以上、本実施例の燃料噴射量制御のための制御則について説明したが、次にこの制御則の実現に当たって電子制御回路30で実際に行なわれる燃料噴射制御処理を第4図に示すフローチャートに沿って説明する。

この燃料噴射制御処理は内燃機関2の始動後繰り返し実行される処理で、処理が開始されるとまずステップ100~ステップ120を実行して、制御に用いる各種パラメータに初期値を設定する。即ちまずステップ100において付着燃料量 f_w 及び疑似付着燃料量 f_{wg} に初期値0を設定し、続くステップ110にてモデルパラメータ P, R の値に初期値 P_0 及び R_0 を設定し、更に続くステップ120にてモデルパラメータ P, R の推定に使用するパラメータ $h_{11} \sim h_{22}$ に初期値 $h_{110} \sim h_{220}$ を設定する、といった手順で初期化の処理を実行する。

次にステップ130においては、上記各センサからの出力信号に基づき、吸気管圧力 P_m 、回転速度 N_e 、冷却水温 T_w 、吸気温度 T_a 、及び燃空比 λ を計測する。そして続くステップ140では、その計測した吸気管圧力 P_m と、内燃機関2の回転速度 N_e とに基づき、内燃機関2の負荷に応じた目標燃空比 λ_r を設定する目標空燃比設定器A2としての処理を実行し、続くステップ150に移行して、吸気管圧力 P_m と回転速度 N_e と吸気温度 T_a とに基づき、前述の(3)式又は予め設定されたマップを用いて筒内流入空気量 m_c を算出する筒内流入空気量推定器A1としての処

理を実行する。

また続くステップ160では、この算出された筒内流入燃料量 mc とステップ130で計測した燃空比 λ とを乗ずることで、筒内流入空気量 $f_c \{=mc(k) \cdot \lambda(k)\}$ を算出する筒内流入燃料量推定器A8としての処理を実行し、続くステップ170に移行して、上記求めた筒内流入空気量 mc とステップ140で設定された目標燃空比 λ_r とを乗ずることで、目標筒内燃料量 f_{cr} を算出する目標筒内燃料量演算器A3としての処理を実行する。そして続くステップ180では、ステップ130で求めた吸気管圧力 P_m と前回当該処理を実行した際に求めた吸気管圧力 $P_m(k-1)$ とモデルパラメータ P, R とに基づき、前述の(4)式又は予め設定されたマップを用いて燃料補正量 δf_c を算出する目標燃料補正量演算器A4としての処理を実行する。

次に続くステップ190～210においては、前回当該処理を実行した際に後述のステップ200、ステップ230、及びステップ260で求めたパラメータ $h_{11} \sim h_{22}$ 、疑似燃料噴射量 f_{ig} 、及び疑似付着燃料量 f_{wg} に基づき、前述の演算式(7)～(15)を用いてモデルパラメータ P, R を推定する同定器A7としての処理を実行する。即ち、まずステップ190において前述の(10)及び(11)式を用いて k_1 及び k_2 を求め、続くステップ200にて前述の(12)～(15)式を用いて $h_{11} \sim h_{22}$ を求め、更に続くステップ210にて、ステップ190で求めた k_1, k_2 と、ステップ160で求めた筒内流入燃料量 f_c と、前回求めた疑似燃料噴射量 f_{ig} 及び疑似付着燃料量 f_{wg} と、に基づき前述の(7)～(9)式を用いてモデルパラメータ P, R を算出するといった手順でモデルパラメータ P, R を推定する。

このようにモデルパラメータ P, R が推定されると、続くステップ220に移行して、この算出されたモデルパラメータ P, R と、ステップ170で求めた目標筒内燃料量 f_{cr} と、ステップ180で求めた燃料補正量 δf_{cr} と、後述ステップ250で前回求めた付着燃料量 f_w とに基づき、前述の(6)式を用いて燃料噴射量 f_i を算出する目標燃料補正量演算器A4、減算器A5及び第1燃料噴射量演算器A6としての処理を実行する。

また続くステップ230では、ステップ210で求めたモデルパラメータ P, R と、ステップ170で求めた目標筒内燃料量 f_{cr} と、後述ステップ250で前回求めた疑似付着燃料量 f_{wg} とに基づき、前述の(17)式を用いて疑似燃料噴射量 f_{ig} を算出する第2燃料噴射量演算器A9としての処理を実行する。

$$\delta f_{cr}(k) = \alpha \cdot \frac{P}{1 - R} \{mc(k) - mc(k-1)\} \cdots (42)$$

また内燃機関2の運転状態に基づき算出される燃料噴射量 f_i の変化量から次式(43)の如く目標燃料補正量 δ

そして続くステップ240では、上記クランク角センサ24からの検出信号に基づき決定される燃料噴射タイミングで、ステップ220で求めた噴射量 f_i に応じて燃料噴射弁32を開弁し、燃料噴射を実行する。

このようにステップ240で燃料噴射が行なわれ、内燃機関2への燃料供給が一旦終了すると、続くステップ250に移行して、ステップ240で実際に燃料噴射を行なった燃料噴射量 f_i と、この燃料噴射量 f_i の算出に用いた前回の付着燃料量 f_w と、ステップ210で求めたモデルパラメータ P, R とに基づき、前述の(1)式をそのまま用いて付着燃料量 f_w を更新する。

また続くステップ260では、ステップ230で求めた疑似燃料噴射量 f_{ig} と、この疑似燃料噴射量 f_{ig} の算出に用いた前回の疑似付着燃料量 f_{wg} と、ステップ210で求めたモデルパラメータ P, R とに基づき、前述の(16)式を用いて付着燃料量 f_{wg} を更新し、再度ステップ130に移行する。

以上説明したように本実施例の燃料噴射量制御装置では、同定器A7によりモデルパラメータ P, R を逐次推定して燃料噴射量算出用の演算式にフィードバックするようにしているので、内燃機関2の経時的変化によって生ずるモデル誤差に起因した制御誤差を良好に補正することができる。また内燃機関2の過渡運転時等にこの推定されたモデルパラメータ P, R に誤差が生じて、これによる制御誤差 δf_{cr} を目標燃料補正量演算器A4で算出して、制御目標となる目標筒内燃料量 f_{cr} を補正するようにされているので、燃料噴射弁32からの燃料噴射量は、内燃機関2の実際の燃料挙動に対応した値となり、燃料噴射量制御を精度よく実行できる。

また本実施例では、特願昭62-189889号等で提案した制御装置の燃料挙動モデル、即ち前述の(21)及び(22)式で記述された燃料挙動モデルをより簡素化した

(1)及び(2)式の燃料挙動モデルに基づき制御則を設計すればよいので、設計が簡単となり、しかも燃料噴射制御のための演算式も簡単となるため、制御のための演算時間を短縮できる。

ここで上記実施例では、目標燃料補正量 δf_{cr} の推定を、(4)式を用いて吸気管圧力 P_m の変化量に基づき行なうものとして説明したが、例えば内燃機関2の運転状態に基づき算出される筒内流入空気量 mc の変化量から次式(42)の如く目標燃料補正量 δf_{cr} を推定するようにしてもよい。

f_{cr} を推定するようにしてもよい。

$$\delta f_{cr}(k) = \alpha \cdot \frac{P}{1-R} \{f_i(k) - f_i(k-1)\} \dots (43)$$

また上記実施例では、制御誤差 δf_{cr} がモデルパラメータ P, R が変化して、吸気管 4 壁面への付着燃料が増大する程大きくなることに着目して、 $\alpha \cdot P / (1-R)$ を比例定数として目標燃料補正量 δf_{cr} を推定するように構成したが、次式 (44) の如く、この比例定数 $\alpha \cdot P / (1-R)$ の代わりに、燃料噴射量 f_i を算出するために求められる付着燃料量 f_w をそのまま用いて目標燃料補正量 δf_{cr} を推定するようにしてもよい。

$$\delta f_{cr}(k) = \alpha \cdot f_w \{P_m(k) - P_m(k-1)\} \dots (44)$$

更に上記実施例では、モデルパラメータ P, R を推定するために同定器 A7 を使用したが、このモデルパラメータ P, R の推定には、必ずしも上記のような同定器を使用しなくてもよく、内燃機関 2 の運転状態を表わすパラメータ (回転速度 N_e , 吸気管圧力, 冷却水温 T_w 等) の関数或はマップを用いてモデルパラメータ P, R を推定するようにしてもよい。

また更に上記実施例では、筒内流入燃料量 f_c を推定する際に、燃空比センサ 19 で検出された燃空比 λ をそのまま用いるものとして説明したが、燃空比センサ 19 からの検出信号には、排気系での排気の流動遅れ、燃空比センサ 19 の検出遅れ等によって、遅れが生ずるので、こうした遅れの補正を行なった上で筒内流入燃料量 f_c を推定するようにしてもよい。

また上記実施例では、内燃機関 2 の各種運転状態を、ステップ 130 において、燃料噴射の度に逐次計測するように構成したが、例えば冷却水温 T_w , 吸気温 T_a 等、変化速度が遅い変数については必要に応じて間引きするようにしてもよい。

また上記実施例では、ステップ 130 ～ ステップ 260 の処理を、内燃機関 2 の燃料噴射と同期して内燃機関 2 の 1 サイクル毎に実行するように構成したが、ステップ 190 ～ ステップ 210 のモデルパラメータの推定処理、ステップ 250 の付着燃料量 f_w の推定処理、及びステップ 260 の疑似付着燃料量 f_{wg} の推定処理について内燃機関 2 の 1 サイクル毎に実行するにすれば、他の処理に関しては、内燃機関 2 の回転とは同期せず繰り返し実行するようにしてもよい。

[発明の効果]

以上説明したように、本発明の内燃機関の燃料噴射量制御装置では、燃料挙動モデルのモデルパラメータを逐次推定して燃料挙動モデルを更新し、その更新された燃料挙動モデルに従い燃料噴射量を算出すると共に、燃料噴射量算出時には、制御目標として、内燃機関の過渡運転時に生ずる制御誤差により補正された目標筒内燃料量が用いられる。この結果、内燃機関の経時的变化によって生ずるモデル誤差に起因した制御誤差を良好に補正することができると共に、内燃機関の過渡運転時等にこの推定されたモデルパラメータに誤差が生じて、燃料噴射量を内燃機関の実際の燃料挙動に対応した値に制御でき、空燃比の制御精度を向上できる。また本発明では、吸気管壁面への付着燃料量を状態変数とした燃料挙動モデルに則って設定された制御則により内燃機関の燃料噴射量制御を精度よく実行できるので、特願昭 62-189889 号等で提案した吸気管壁面付着燃料量と吸気管内での蒸発燃料量とを状態変数とした燃料挙動モデルに則って燃料噴射量制御を行なう装置に比べ、制御に用いる各種演算式を簡素化でき、燃料噴射量制御のための演算時間を短縮できる。

【図面の簡単な説明】

第 1 図は本発明の構成を表すブロック図、第 2 図は実施例の内燃機関及びその周辺装置を表す概略構成図、第 3 図は電子制御回路による燃料噴射量制御のための制御則を表わすブロック図、第 4 図は電子制御回路で実行される燃料噴射量制御処理を表わすフローチャート、である。

M1, 4……吸気管、M2, 2……内燃機関

M3, 32……燃料噴射弁

M4……モデルパラメータ推定手段

M5……付着燃料量推定手段

M6……目標筒内燃料量算出手段

M7……制御誤差推定手段

M8……目標筒内燃料量補正手段

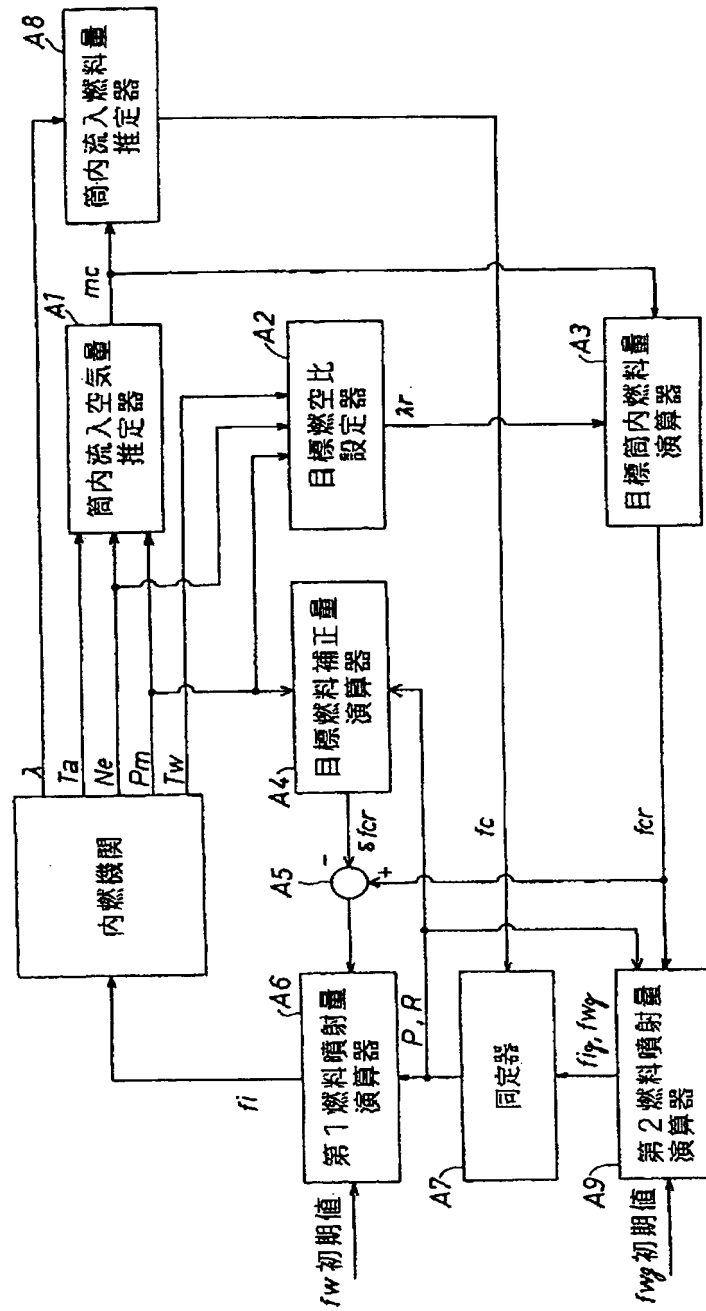
M9……燃料噴射量算出手段

12……吸気圧センサ、14……吸気温センサ

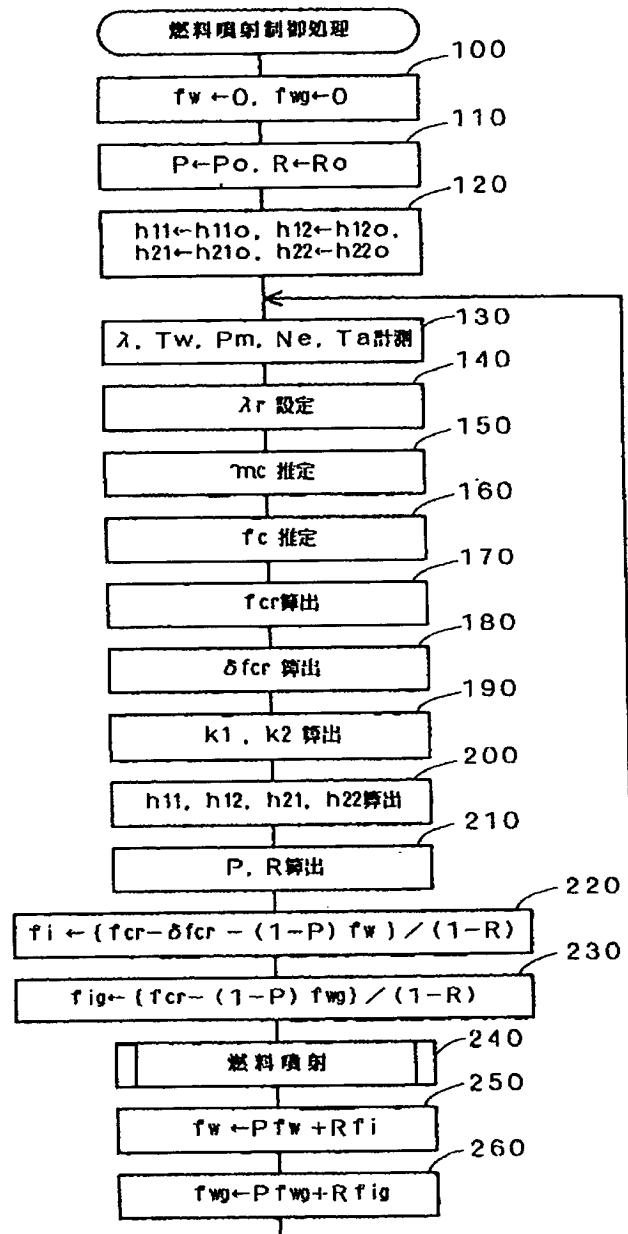
22……回転速度センサ、26……水温センサ

30……電子制御回路

【第3図】



【第4図】



フロントページの続き

(58) 調査した分野 (Int. Cl. 6, DB名)
F02D 41/00 - 41/40